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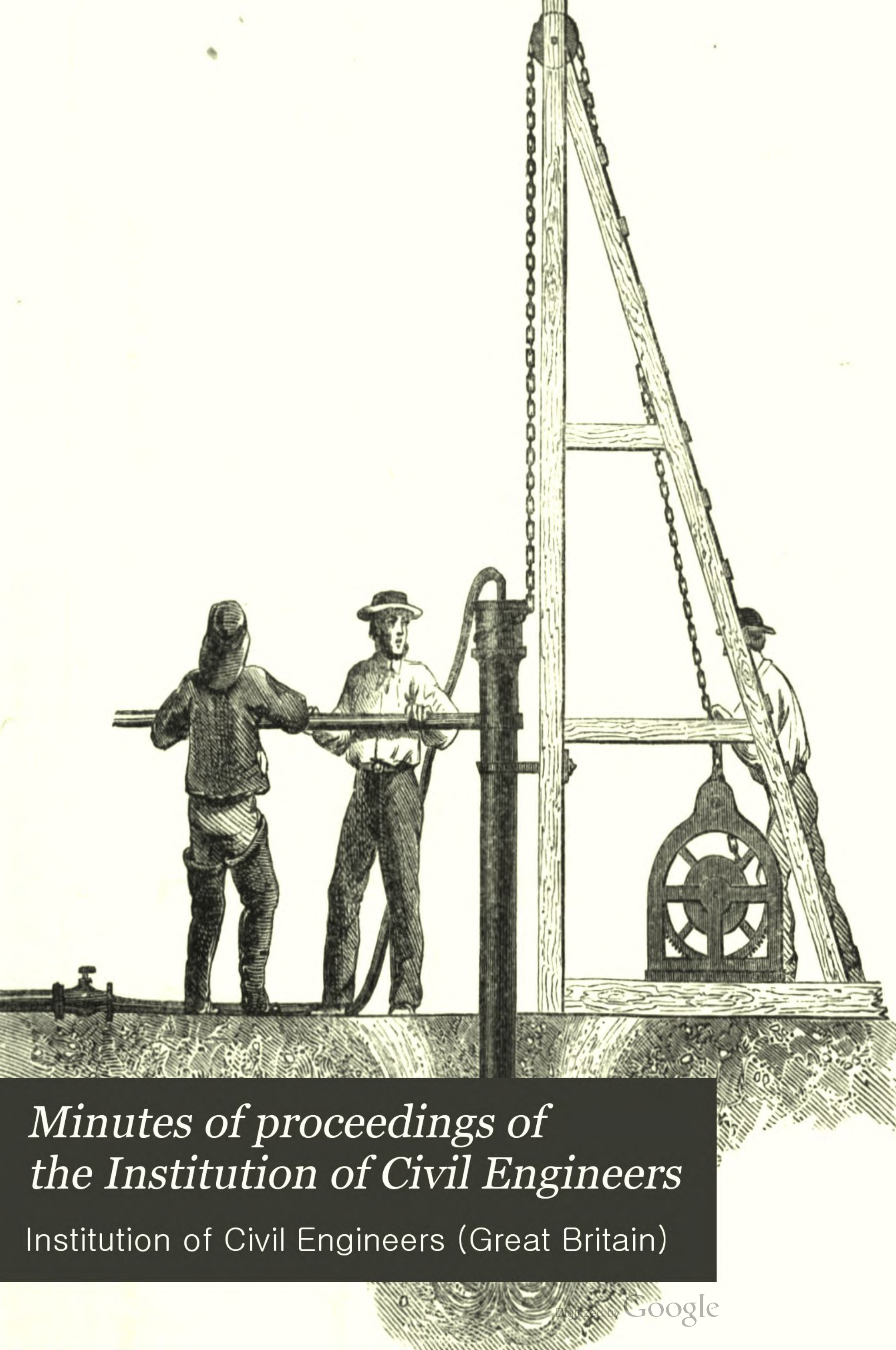

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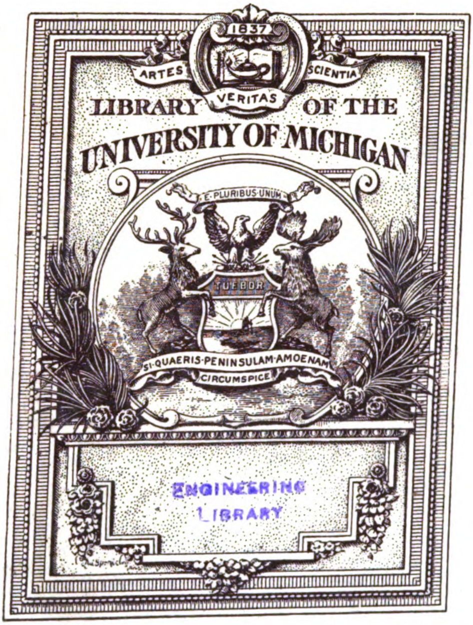
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MINUTES OF PROCEEDINGS

OF THE

INSTITUTION

OF

CIVIL ENGINEERS;

WITH

ABSTRACTS OF THE DISCUSSIONS.

VOL. XX.

SESSION 1860-61.

EDITED BY

CHARLES MANBY, F.R.S., M. INST. C.E., HONORARY SECRETARY;

AND

JAMES FORREST, ASSOC. INST. C.E., SECRETARY.

INDEX, PAGE 587.

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INSTITUTION
OF
CIVIL ENGINEERS.

SESSION 1860-61.

November 13, 1860.

GEORGE PARKER BIDDER, President,
in the Chair.

At the commencement of the proceedings, Mr. Bidder,—President,—thus addressed the Meeting:—

Gentlemen,

At the opening of the last Session, you heard from the then President, Mr. Locke, a most feeling Address, announcing the deaths of those two distinguished members of the profession, Brunel and Stephenson. How little was it imagined, that the lips which then uttered the fervent eulogy upon the memories of his departed friends, would so soon be hushed in the silence of the grave. Another of the leaders has passed away, cut off in the prime of life, and in the full vigour of his intellect. In Mr. Locke, the profession has lost one of its most eminent members, whether regarded professionally, or socially, and the Institution one of the ablest Presidents that have occupied that distinguished position.

Sprung originally from that great nursery of practical Engineers, the works at Newcastle-upon-Tyne, Mr. Locke acquired there his mechanical knowledge, and his unbounded confidence in the powers of the locomotive engine. He was soon transplanted to co-operate with Mr. George Stephenson, in several of his early works, and nearly at the commencement of the construction of the Grand Junction Railway, the separation occurred between them, into the causes of which it is as unnecessary, as it would be invidious to enter. This separation between the master and pupil occasioned painful feelings at the time, but it must now be looked upon as having been inevitably necessary for the more rapid development of the railway system, at the period when the existing modes of transit had become totally inadequate for the requirements of commerce, and for the growing wants of civilisation. It has always been observed, that whenever the necessities of society require any peculiar development of talent, or any particular invention, the man and the knowledge are, by the interposition of an all-wise Providence, forthcoming to provide for the growing wants of society. On the introduction of railways, it was requisite, that a vast amount of mental energy and of physical exertion should be employed, in order to render the development as rapid as possible. Mr. Locke possessed peculiar qualities of mind which secured for him the confidence of capitalists, by whom the construction of the Grand Junction Railway was intrusted to him.

At an early period of the railway epoch, he became the Engineer of the South Western Line. He was thus, almost naturally, led to seek for what he ultimately accomplished, the extension of the system to France; where, in the construction of the Paris and Rouen, and Rouen and Havre Railways, he introduced English capital, English workmen, and English contractors, and initiated the Continental Railway System. He was thus the first who promoted the establishment of the present rapid communication between the great commercial capital of Great Britain, and Paris, the fashionable metropolis of the Continent.

Returning to the field of his early labours, he undertook the extension of the lines from Preston to Carlisle, thence to Glasgow, Edinburgh, and ultimately, to Aberdeen, thus becoming also the pioneer of the Scotch Railway System.

Without entering minutely into the details of his professional life, which will be given in the Official Memoir, it will be admitted, from what has been stated, that Mr. Locke was entitled to be considered one of the great Engineers of the period, and a distinguished pioneer in the introduction of the railway system.

There has been a curious coincidence in the circumstances attending the deaths of the three distinguished men who have been removed, within little more than a year. Each has departed on the eve of, or at the completion of, some great work. Mr. Brunel may be said to have died, as the 'Great Eastern' steamer commenced its trial voyage;—Mr. Robert Stephenson was taken away, on the eve of the completion of the great Victoria Bridge over the River St. Lawrence;—and Mr. Locke's decease occurred, on the consummation of his long-cherished project, the extension of the narrow-gauge line to Exeter, the capital of the West of England.

These remarks would be very incomplete, if no allusion were made to the distinctive features which marked Mr. Locke's professional career. They will be best understood, by extracts from the able Address he delivered, on assuming the Presidential Chair, only three years ago. He then said:[1]—

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xvii., pp. 150, 151.

"Let us consider the principle on which public works are now undertaken:—the motives that supply those abundant means by which, alone, they become possible. It must be seen, that the problem proposed, on such grounds, to practical science, is, not merely the execution of certain works, but rather their arrangement and construction in a manner calculated to realise the objects in which they originate. * * * *

"Beyond this,—observing the springs from which our profession draws its support, and the relation which it bears to the voluntary employment of private means in public works,—the significance of financial results, as final exponents of their success, or failure, must be apparent. * * * * * *

"In every point of view, therefore,—whether especially considering, that it is the triumph of science to solve the whole of every problem submitted to it, and not a part only, or regarding its general relations to the objects of modern society in inviting its exercise;—it will be seen, that the financial result of their joint operation is not their least important feature, and that the appreciation of this side of the question really concerns the Engineer, no less than the Statesman, or the Capitalist."

Those who have watched the career of Mr. Locke, are well aware how pertinaciously he adhered to these rules. It was not that he feared engineering difficulties, for when they were inevitable, he encountered and overcame them with skill; as for instance, in the works of the Manchester and Sheffield Railway. But his great anxiety, which secured for him the confidence of a large body of capitalists, was to attain his object by avoiding difficult and expensive works, from a desire, that all the works on which he was engaged, should be commercially successful. The abnegation of professional renown, arising from the construction of monumental works, whilst establishing his reputation as an economical Engineer, induced him to turn to the locomotive engine, and to tax its powers, in which he had, from the earliest period, the greatest confidence, for overcoming steeper gradients than had, hitherto, been deemed compatible with economy and safety. In this he was very successful, and when viewed in conjunction with the general features already mentioned of his professional life, it must be conceded, that the decease of Mr. Locke has caused a gap in the profession which will long be felt.

It would be improper to close this hasty sketch, without alluding to the extent to which both Mr. Locke and Mr. Robert Stephenson acquired the confidence and esteem of a large circle of friends, in the House of Commons. They ably maintained the dignity and the independence of an important profession, which should always be adequately represented in Parliament. They went there without any personal objects, beyond that of fair ambition to attain an honourable position; whilst there, they were eminently useful, and it is to be hoped, that before long, other active and useful members of the profession will assume places in that House.

Of the urbanity and impartiality with which Mr. Locke acquitted himself of the duties of President, it is unnecessary to say a word; all that he said and did is so recent, and has been so universally approved. The Members of Council, and those who enjoyed his friendship, will long lament the loss of a genial companion, and the Institution a valuable and influential Member.

The discussion upon the Paper, No. 1,028, "On Breakwaters," by Mr. M. Scott, which was commenced at the last Meeting of Session 1859-60,[1] was resumed, and occupied the entire evening, to the exclusion of any other subject. The whole of the discussion is printed consecutively, in the Minutes of Proceedings for 1859-60.

November 20, 1860.

GEORGE PARKER BIDDER, President,
in the Chair.

No. 1,026.—"On the River Orwell and the Port of Ipswich."

By George Hurwood, M. Inst. C.E.

The Author has been induced to prepare this Paper, from the remark made by the President,[2] during the discussion of the Paper, "On Arterial Drainage and Outfalls," by Mr. Grantham, (M. Inst. C.E.,) that it would be rendering valuable service, if faithful records of the treatment of rivers, with the results, were submitted to the Institution.

Ipswich is the chief town of the County of Suffolk. The population in 1851, at the time of the last census, was 31,215, but it has been increasing for many years past, and it may now be taken at several thousands above that number.

The River Orwell constitutes, more properly, an arm of the sea, inasmuch as the inland navigable River Gipping, of which it was formerly a continuation, now terminates with a lock, within the limits of the borough of Ipswich. The Orwell extends from this lock, and a small side creek a few hundred yards above, which is covered with water at high tides, to the fine and capacious harbour of Harwich, twelve miles distant from Ipswich. The jurisdiction of the Ipswich Dock Commissioners extends to Downham Reach, and they have, hitherto, exercised control over the whole river.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xix., p. 651 *et seq.*
[2] *Ibid.*, p. 105.

The following observations refer to the state of the river and port, about the beginning of the present century. That period is selected, because from that time, there exist good data for tracing the leading points of management and treatment to the present day. Prior to the passing of an Act of Parliament, in the year 1805, for the improvement of the river, the Corporation of the town had the sole management and control of the port and river; and so seriously had the latter been encroached upon and neglected, and the funds arising therefrom, been misappropriated, that great injury was inflicted upon its trade and commerce. The leading merchants, shipowners, and inhabitants, had, for many years previously, felt the grievance, and they combined for the purpose of taking active measures to correct the abuses. A Committee was appointed to undertake the management, and after due deliberation, it was determined, that an Engineer should be employed to survey the river, and prepare plans for its improvement. The services of Mr. William Chapman, of Newcastle-upon-Tyne, were engaged for that purpose. In May, 1797, he submitted a Report, with two plans, and estimates of the cost of carrying the proposed schemes into effect. Early in the year 1803, the Committee called a public meeting of the inhabitants to consider the subject, when it was almost unanimously determined to apply to Parliament for powers to improve the river, as suggested by Mr. Chapman in his plan No. 2; or at least, so much of it as the state of their finances would permit. This resulted, after considerable opposition from the Corporation, in obtaining the Act of Geo. III., cap. 101, in 1805, by which the managing power was virtually taken out of the hands of the Corporation, and was placed in those of the principal merchants, shipowners, and inhabitants of the town.

The condition of the river and port, at this time, is given in the following extracts from the Report of the Committee:—

"The channel, for about two miles from the quays, but more particularly so for the first mile, is materially reduced in width and depth, and the navigation thereof becomes intricate and difficult. The force of the tides flowing and ebbing, being thus impeded, the soil deposits more rapidly than formerly, and lessens the supply and depth of water, which, usually, at neaps, is only about 5 feet, and at spring tides, 8 feet at the quays, whereby much inconvenience and expense are caused to the trade of the port, from the detention of shipping, which frequently has to wait ten days for a tide, in getting to, or from the wharfs; and it sometimes occurs, that there is not a tide during springs sufficient to remove the shipping, without the expense of lighterage and porterage, during which, the goods are exposed to suffer much peculation and waste, and if of a perishable nature, to injury also. * * * It is true they, [the Corporation,] are the supposed conservators of the soil of the river, and it is admitted, that they have faithfully preserved it from injury, by not suffering it to be removed for the accommodation of the trade and shipping; for want of which, the evils now complained of have principally arisen. * * * It is very usual for vessels to deliver and take in their cargoes, about three miles below the wharfs at Downham Reach, into small craft, at an additional expense beyond what would be incurred, if ships came up to the wharfs; for coals, of not less than 1*s.* 6*d.* per chaldron, on corn nearly 1*d.* per quarter, and on other goods, * * without calculating the loss for waste and peculation, which, indeed, is difficult to estimate, from the impracticability of ever seeing the transactions carried on so far from the wharfs; all which falls upon the merchant and consumer. * * * These combinations of circumstances have, at different times for the last eight, or ten years, engaged the attention of some of the principal merchants and inhabitants of the town and port of Ipswich. * * * It is the opinion of an able Engineer, that nothing short of the proposed improvements will be effectual in rendering the needful accommodation, or will put the river in such a state as the present trade of the port requires.

"The town of Ipswich consists of about 13,000 persons, exclusive of military, * * and about 6,500 to 7,000 tons of shipping belong to the port."

As before stated, Mr. Chapman, in 1797, submitted two plans, Nos. 1 and 2, with a Report of considerable length, from which the following extracts are taken:—

"Previously to the discussion of the two different schemes which I have to offer for the improvement of the navigation to the town of Ipswich, I will make some observations on the causes of the present bad state of the river above Downham Reach, which was formerly, and even in the memory of man, much better than at present. * * The obvious cause of the channel to Ipswich being so bad, is the reduction of the tide water which, in the progress of nature, will always be growing less from the deposit of silt, but in this instance, occasioned, principally, by the inclosure of lands from the river. A part of Ipswich has, no doubt, been acquired from the ooze, but what has more particularly affected the river, has been the inclosure of, as far as I can judge from the plans, about 120 acres above Stoke Bridge, except such part as is now used for the tide mill, which so far produces a greater effect than formerly, as it is let off after the river has subsided, into a narrow channel; and also of about 60 acres between Stoke Bridge and Nova Scotia, which system still continues to exist, as still more recently, about 6, or 7 acres have been taken in, between the cliff brewhouse and the rope yards. These causes have nearly destroyed the port of Ipswich, and a remedy becomes absolutely necessary.

"You called upon me to give an opinion upon the straightening and embanking the course of the river downwards, which might have been done with some improvement of the navigation, and great advantage as to the value of the land acquired; but the certain result of this would be, that a nearly equal extent of the river below Downham Reach, would become unnavigable as the present river down to Downham Reach, and if the same system were pursued, it would finally destroy the harbour of Harwich.

" The two schemes, or modes that occur to me, are the making of a sea lock at the head of Downham Reach, for vessels of 15, or 16 feet water to enter at all tides, and proceed by a canal to the common quay; or otherwise, the improvement of the navigation itself.

"The former is what I shall first explain. * * The advantage of this plan is, that vessels of sufficient magnitude may, at all times, go from and to the common quays at Ipswich, to Downham Reach, without regard to tides, or winds; as they may be tracked by horses all the way, and there will be no want of depth of water, although some untoward circumstances prevent its being so perfect and easy of execution, as it otherwise would have been. What I allude to, is the impracticability of obtaining land water to supply the channel, on such elevation as would be most easy of execution, without purchasing the tide mills and the next mill above them; and the impracticability, even then, of making a watercourse to the town, without an expense beyond the effect to be acquired; and also the incapability of extending the canal navigation, effectually, to the warehouses and quays, on account of the tide mill and marshes above Stoke Bridge, which could not obtain a drainage, or the mill water a passage, without a long tunnel of vast expense. These evils are, however, in a great degree obviated, by making the channel, the major part of the way, with one bank only, and consequently, flooding a considerable quantity of ooze on the inside, which, in the period intervening between the height of spring tides, would not sensibly be lowered by the consumption of the lock, in passing all the vessels that might come; and also by making a lesser lock suited to vessels under 25 feet beam, by Stoke Bridge. The expense of this plan would, according to the estimates, amount to about £27,000. * *

" Another cause, besides that I have mentioned, of the badness of the navigation, is the great crookedness of the river, which, exclusively of giving the water a less fall in a given space, checks the effect of its velocity and renders the navigation extremely difficult even for small craft. * * In laying out the new course, I have availed myself of the present channel of the river, as much as might be consistent with regular curvature, of course, and have also avoided going into the higher part of the ooze. A small curvature consistent with the width of the river is no detriment. * * *

"I will now proceed to make some observations on the present state of the river, from Freston Reach to Ipswich. At the head of Freston Reach, there are 10 feet at low water; and spring tides rise there nearly 12 feet, when they rise only 8 feet at Ipswich Quay upon a low-water channel of little more than a foot deep; consequently, there is a fall of nearly 4 feet in the surface of the river, and 13 feet in the bed of it; there is also more than a proportionate width of channel. The distance between these two points is, by the present crooked course of the river, 3¼ miles, and by a right line, barely 2 miles. The greatest curvature takes place immediately above Freston Reach, from the head of which it strikes off nearly at right angles, and after a circuit of half a mile, arrives at the north end of the channel that dries before three-quarters ebb, called Round Ooze Lake, which is little more than 200 yards long. From thence, tracing the river upwards to Fenn Bight, the distance is half a mile, and the course of the Black Ooze Lake is but 500 yards. These two lakes form a high-water channel in a right line from Fenn Bight to the head of Freston Reach, and would, undoubtedly, have become the regular channel of the river, if it were not, that they are protected from deepening, being covered by the long fibrous grass, common to the rest of the ooze, below neap-tide high-water. On the covering of the ooze, which takes place at half-flood, and previously to its covering, the tide sets with considerable velocity through those channels, which are only from 6 to 18 inches lower than the adjoining part of the ooze. * * The main channel, notwithstanding the crookedness of the course, still continues of several feet depth at low water, near Upper Hearth Point, decreasing, however, considerably in width; from thence upwards, the bed of the river rises, and is not navigable for boats at low water.

"The plan No. 2 shows the present channel of the river, as laid down by Mr. Bransby's survey, and the proposed altered course, which shortens the distance from Stoke Bridge to Freston Reach, full one mile, * * and at the same time, it avoids, as much as may be, the high part of the ooze, and coincides with the bed of the river, in several parts. The width of the new course of the river, as I have laid it down, is nearly what I suppose it may naturally assume, if the full extent of the proposed plan be carried into effect. * * I, however, by no means recommend the formation of so wide a channel throughout, as I have drawn it, but only to excavate between the red lines, and to defend the concave shore, by groins and jetties, and to leave the river to do the rest. Straightening alone, without producing an additional current of water, would not be productive of sufficient effect, but if an equivalent can be obtained to the quantity of water that flowed over the land that has been embanked from the river, this, in aid of the greater straightness of course, must produce the effect desired. By running a bank in front of the quay from the head of the proposed cut * * to below Lower Hearth Point, and closing it to the east shore, [with flood-tide entrance gates,] a reservoir of 80 acres of 5 feet average depth at spring tides, would be found, and all the water to fill and empty it would pass up and down the channel which, to the lower extent of that reservoir, would produce a similar effect, or nearly similar to what an equal quantity of water, overflowing the marshes above Stoke Bridge, did formerly. * * In the making of the two channels, (that for the combined waters, * * and that in front of the quay from the reservoir,) the earth, or silt raised, will form a valuable island on which I have sketched outlines of quays, &c. * * * From these causes it is clear, that unless attended with great expense, it will be advisable to carry this plan into effect * * the sum I have estimated the works to cost is £17,000. * * In process of time, but at some distant period, the proposed reservoir will silt up so far as to fail of its full effect, and * * the ooze bordering the channel of the lower part of the river, will likewise rise; but the remedy will not be difficult, and should you apply to Parliament for the improvement and conservation of the Orwell, it may be prudent to provide for it, by obtaining the dominion as conservators of the river, from shore to shore."

In March, 1803, Mr. Chapman addressed to the Committee another Report of considerable length, in which he states:—

"In my Report of May, 1797, I had the honour of laying before you two plans; the first of them was to rise by a tide lock near Downham Reach, and to communicate from thence by a canal to a basin before the town. But as this, at that time, did not appear to me capable of including the warehouses, west of the common quay, without an expense more than adequate to the end, I was inclined to prefer the second plan, which by the measures pointed out, [viz., cutting off the abrupt turns, and improving and deepening the bed of the channel,] would have given deep water and equal accommodation to all the warehouses in the town, which bordered on the river. The latter plan was only applicable to the use of such vessels as will bear the ground; therefore, as on further inquiry, I find it highly probable, that the future commerce of Ipswich may require copper-bottomed vessels, I recommend, that if any considerable expense be incurred, it should be in the execution of such a work, as will give this rising town the means of carrying its trade to the extent it is capable of, or otherwise, that you content yourselves with obtaining a few feet more water up to the quay."

In the concluding part of this Report, Mr. Chapman endeavours forcibly to show the advantages that would result, by carrying into effect plan No. 1, which he strongly recommends.

In November of the same year, a further Report was made by Mr. Chapman, in which he again enters fully into the advantages, both financially and otherwise, which would follow the execution of plan No. 1, but instead of proposing a navigable depth of 16 feet, as recommended in his first Report, he reduces the depth to 13 feet, which, he states, he was induced to do from having had the soil tested by borings which, in some places, were not so favourable for his project, as he had, at first, conceived. No doubt, the lessening of the cost was also another reason for his reducing the size of the lock, the depth of water, &c.

So very desirable was it, in the opinion of Mr. Chapman, to adopt the plan No. 1, that he again pressed the consideration of the subject, in another long Report in the following year, 1804, making a further modification of it, by shortening the length of the canal, and placing the entrance lock at the head of Freston Reach, instead of at the former place. It appears, however, that after this Report had been read before a full meeting of the committee of subscribers, on the eve of a public meeting of the inhabitants, the opinion was so general, that the improvements, as shown by plan No. 2, would be all that the trade required at the time, and could, with propriety, be undertaken, that Mr. Chapman, by way of postscript to his Report, writes:—

"From the bent of public opinion appearing to me to be in favour of simply deepening the river and cutting off some of the bends, * * it appears to me clearly advisable not to bring forward my Report at the general meeting to-morrow, because by creating a secession from those who are in favour of the only plan likely to be carried into effect, it may prevent anything whatever being done. Although I still decidedly prefer the plan recommended, yet the other will, undoubtedly, be an improvement of material moment to the present state of your navigation."

In the following year, 1805, an Act of Parliament for improving the river was obtained.

The Author feels it may be considered, that in this communication, he has made extracts of unnecessary length from the Reports of Mr. Chapman; but his object has been to give a prominent place to the views of that Engineer. It is only due to him to state, as will subsequently appear, that in his plans and Reports, he clearly expressed his views of the works that should be undertaken to improve the port and river, and these plans have, with certain modifications, been approved and acted upon by succeeding Engineers.

After the passing of the Act, the first work of importance undertaken by the Commissioners, was the excavation of a new channel, so as to cut off the awkward bend, A, by Cliff Reach; (Plate 1.) To facilitate the operations, Mr. Chapman availed himself of one of those indispensable appliances for the improvement of rivers, the steam dredger. Judging from a Report by him, upon first setting the engine to work in May, 1806, it is believed, that this was one of the earliest dredgers worked by steam. Since its introduction, the port has always possessed an engine of the kind, and to its operation during so many years, the river owes its present improved condition.

About the year 1819 a new channel, B, (Plate 1,) was cut through Round Ooze, by which the necessity of using the circuitous and difficult channel by John's Ness, was avoided; and in the year 1821, under the advice and superintendence of Sir William Cubitt, (Past-President Inst. C.E.,) a new channel, C, (Plate 1,) was cut, from the upper end of Lime Kiln Reach to the lower end of Hog Island Reach.

The works undertaken by the Commissioners had so far improved the channel of the river, that in 1826, vessels drawing about 11 feet of water, could reach the quays at spring tides. Notwithstanding the necessary outlay for these works, the Commissioners had also saved, at this period, from the revenue of the port and river, the sum of £25,000, which enabled them to effect further improvements. Powers were obtained in 1837, under the Act of 1 Vic., cap. 74, to make a wet dock, and the works were immediately commenced under the direction and superintendence of the late Mr. H. R. Palmer, by the authority of the Dock Commissioners, who were also intrusted, under the Act, with the management of the river. At the commencement of the year 1842, the works were sufficiently advanced to maintain the float. Upon the retirement of Mr. Palmer in that year, the Author succeeded him, and has since held the appointment.

In 1845, the cutting for a new channel, D, (Plate 1,) through Black Ooze was commenced, and it was completed in 1847. The curves from Cliff Reach to the Upper Hearth Point, the Lower Hearth Point, and also Wherstead Reach Point, where awkward projections existed, have all been considerably reduced. The channel from the lock of the wet dock to the deeper water near Downham Reach, has been dredged to a level bottom, nearly a foot lower than the top of the lock cill; and all the shoals are removed, as soon as possible, after their discovery. The effect of these continuous and combined operations through a series of years, has been, to give a clear depth of water from the sea to the wet dock, of 16 feet 4 inches, at average spring tides, and an average low-water depth of not less than 3 feet 3 inches throughout the channel, from the dock to the sea.

It may be observed, that when the wet dock was opened in 1842, vessels of about 13 feet draught, could reach the dock at average spring tides. Since that period, it has been an object, not only to increase the depth of water by dredging, but also to regularise, by degrees, the course of the channel, thereby making it less difficult to navigate, and at the same time, giving greater freedom for the flow and ebb of the tide. This is very important; for upon the tidal operations, the preservation of the river entirely depends, and every available means have been adopted, to encourage the easy flowing of the tide, to enlarge the area which receives it, and to prevent any encroachment upon the space it covers, particularly in the upper part of the river. The water from the sea is very clear, and leaves no perceptible deposit. But near the town, an increasing deposit is taking place, on account of the sewage being improperly discharged into the river by the corporate authorities, against the remonstrances of the Dock Commissioners.

The following are the particulars of the tides of the Orwell, taken from the Admiralty Survey of 1844 :—

	High Water, F. and C.		Rise and Fall.			High Water, F. and C.		Rise and Fall.	
	H.	M.	Ft.	In.		H.	M.	Ft.	In.
Harwich . . .	12	0	11	6	Mulberry Middle.	12	27	12	2
Pin Mill . . .	12	20	11	11	Ipswich Dock .	12	35	13	7

At Ipswich Dock, the average rise of neap tides is 8 feet 8 inches. The average depths upon the lock cill, are :—

	Ft.	In.		Ft.	In.
High water, spring tide . .	16	4	Low water, spring tide . .	3	3
„ neap tide . .	13	5	„ neap tide . .	4	9
Mean high water of all tides	14	10	Mean low water of all tides	4	2

The rate of spring tides, within two miles, or three miles of Ipswich, is about 1¾ knot per hour. The periods of duration of the flood and ebb tides at Ipswich Dock are very nearly equal, and the stationary state of the tide at low water is of short duration, and seldom perceptible.

The port has but one dock, the area of which is about 33 acres; it is accessible on all sides, and the quays are connected with the railway. The length of the lock between the gates is 150 feet, and the width is 45 feet.

The cost of the wet dock and of the works connected with it, has been about £130,000. The money was borrowed on the security of the dues, at a fixed rate of interest which has been punctually paid, and a balance is annually left in favour of the port.

The Commissioners of the port, in whom the governing powers are vested, are chosen and elected in the manner prescribed by the Act of Parliament, 1 Vic., cap. 74, clause 14. They annually elect a Managing Committee, which meets regularly every month, (formerly every fortnight,) and oftener, when requisite. Their proceedings are carefully recorded and are submitted, monthly, to the general body of the Commissioners, for their approval and decision. It may be observed, that although the Managing Committee is annually chosen, it has resulted in the same Chairman and Committee being re-appointed, with some few and unavoidable changes in the latter. These continuous services have been attended with no small advantage to the port.

Before closing this Paper, there is one point to which the Author would call attention, as it interests the port of Ipswich, and may be followed with advantage by other ports similarly circumstanced. The soil raised during the improvements of the river is supplied to vessels, as ballast, realising by its sale, very nearly the expense of obtaining it.

The result of the treatment of the river has been, to increase the depth of water at Ipswich quays, from 8 feet, before the commencement of the works, to 16 feet 4 inches, or more than double, since their completion. At the former period, the tonnage of the registered vessels belonging to the port, was about 7,000 tons; at the present time, it amounts to 16,274 tons.

The Paper is accompanied by an Appendix, containing Reports of Mr. W. Chapman, Mr. H. R. Palmer, and Mr. G. Hurwood, as well as statements of accounts, showing the income and expenditure at different periods; and by three Plans illustrating Mr. Chapman's Reports.

Mr. PETER BRUFF, having resided at Ipswich for many years, and having been in the habit of passing along the river, had observed the proceedings of the Dock Commissioners with satisfaction, and he considered that, upon the whole, the works had been successfully carried out. During the last twenty-five years, the port had assumed a totally different character. The improvements were still progressing, and would have advanced, he believed, to a much greater extent, but for the unfortunate antagonism that existed between the Commissioners and the Railway Company, which had seriously crippled the resources of the local authorities. He had read the Reports of the eminent Engineers referred to, with some attention, and he confessed he should have preferred to have seen the more extended plans of Mr. Chapman carried out, rather than the restricted operations of the Dock Commissioners, which seemed, however, to have been mainly adopted from financial considerations.

There were one, or two features of interest connected with this subject. The straight cut marked C (Plate 1), in the upper part of the estuary, was connected with a crooked channel to the westward, which formed part of the old tideway course. It was a singular fact, that although the straight cut had been made about fifty years, the circuitous channel was still open, and up to within a short period it was a good, if not the best, navigable course. He had heard seafaring men complain of the straight cut, as an undesirable alteration for the port. He believed the principal objection was, that to the eastward it hugged the high land, which rose abruptly from the river, and was thickly wooded, so that when vessels got into that part of the channel, they were baffled in their sailing course. Following the estuary downward to the point marked B, where there was another circuitous part of the old channel which continued open, it would be observed, that there was a straight cut uniting two considerable bends, which had been carried out under the direction of the Author of the Paper. This circuitous channel to the westward of the straight cut, had the deepest water; it was so, at all events, until a very recent period; and steam boats at low-water spring-tides invariably took that course. The Author had correctly stated, that the sea carried very little deposit into this estuary; the sand held in suspension by the flood tide, appeared to be deposited before entering the channel. He thought Mr. Chapman was wrong in the opinion, that those mud banks, or flats, would gradually silt up; for he did not believe, that they had risen within the memory of man. They were not ordinary mud banks, but fixed alluvial flats covered with marine vegetation, and they tended materially, he considered, to keep open the channel to the depth which it maintained. The descent of the tide, at about one-third of the ebb, was very strong, and when drawing off the flats, the water in the channel ran as from a sluice. It would have been desirable to show the maximum run of the ebb tide at that period.

The actual efficient condition of the Orwell was due, he believed, to those great receptacles of tidal water which had been referred to. There had been very little embanking of the lower part of the estuary, except the small lateral valleys. This was to be ascribed to the fact, that the land, when reclaimed, was of little value for agricultural purposes.

It was a misnomer to call the Orwell a river; it was, properly, an estuary of the sea, terminating at Ipswich, where it received a small fresh-water stream called the Gipping, from which probably the town derived its name;—Gippeswick, otherwise Ipswich. The Gipping flowed from about twenty miles above Ipswich, its source being near to Stowmarket, which was only distant about twelve miles in a direct line. In connection with the valley at the head of this estuary, he would mention a curious circumstance, from which, however, he could not draw any very definite conclusion. When the Eastern Union Railway was in course of construction, in the vicinity of that town, across a small marsh bounded on two sides by high ground, the line at that part, within a short time of its expected opening, suddenly disappeared. No borings had been made at that spot, the line being nearly on the surface of the ground, which gave no indication of unsoundness, although, as it afterwards turned out, it was the surface of a 'mere,' or small lake, thickly covered with vegetable matter, upon which trees of considerable size were growing. In the course of a few hours after the breaking of this vegetable crust, a depth of 40 feet of water was found at the spot; and on further investigation, it was discovered, that this mere was funnel-shaped, with a bottom of clean sand and shingle, and more than 100 feet deep, or a few feet below low water of the Orwell. From this circumstance, and from finding a considerable depth of peat in various parts of the valley, he had little doubt that, within a comparatively recent period, the tidal flow formerly extended much further into the interior than at present.

In answer to questions from the President, Mr. Bruff said, that he thought the fresh water at Ipswich, was positively detrimental to the channel of the Orwell. A few years ago, he had some conversation with Captains Washington and Vetch, (Associates Inst. C.E.,) as to the variation in the time of high water, between the entrance of the Orwell at Harwich Harbour and its termination at Ipswich. To the best of his recollection, it was then stated to be rather less than half an hour. If that was the case, it was a remarkable circumstance, because it was nearly as fast as the tide wave travelled along that part of the coast.

was convinced, from all the observations he had made, and from all the study that he had given to the subject, that the land water was of material importance in keeping an estuary open; although, in some cases, its effects might have been exaggerated. If the amount of land water was only one-twentieth of that of the sea water, the effect being as the squares of the velocity, the downward sweep of the tide as compared with the upward, would be increased in the proportion of 10 to 9.

Mr. FREDERICK BRAITHWAITE observed, that without land waters, there would be no rivers; for the surplus rain was the source of mountain rills and valley springs, whence were formed streams, rivulets, and rivers, which, eventually, found their way to the sea and became tidal. Had it not been for the great increase of the land water consequent upon the large rainfall, the Thames would have borne a greater resemblance to a salt-water tidal creek, than to a fresh-water river.

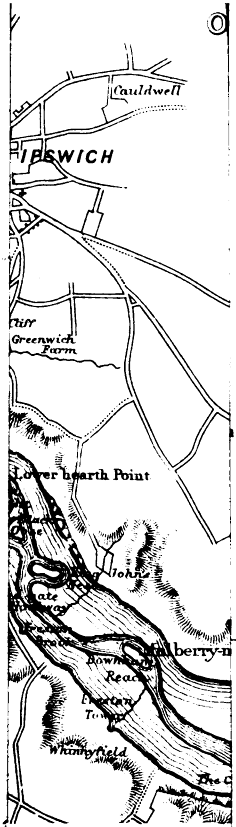
Mr. REDMAN said, as far as he recollected, a question was raised, according to the Report of the Tidal Harbours Commissioners of 1845, as to the policy of depositing material, excavated from the artificial channels, into the natural channel in the crooked reach of the Orwell, B, (Plate 1,) and in the Report of the inspecting officers, Captains Washington and Vetch, it was strongly objected to. It was, he believed, in consequence of that objection, that the intention of depositing the excavated material in the natural channel, was abandoned.

Mr. HURWOOD replied, that when the Black Ooze cutting was under consideration, he suggested, that it should be made, and that it was desirable to prevent the strength of the tide running round the deep old channel called Back Again Reach and John's Ness. His object was to confine the run of the tide, both on the flood and on the ebb, to one channel, and the work was begun; but Captains Washington and Vetch, not considering it important, it was, at once, stopped. That channel was still open, but there was a certain amount of deposit in it. The particulars relating to the subject would be found in the Reports, &c., which he had submitted to the Institution, with the Paper; as also a detailed account of the cost of the works.

In answer to a question from the President, Mr. Hurwood said, that the old channel, by Wherstead Lane Reach, still remained, at present, deeper than the new cut through Black Ooze.

Mr. J. COCKBURN CURTIS called the attention of the Meeting, to the difference between the range and the velocity of the tidal wave, in its passage up the Rivers Orwell and Stour, (Plate 1.) at high-water spring-tides, as shown by the results of the tidal observations made during the Admiralty Survey of 1845, from which, for the purposes of comparison, he had compiled the following Table:—

PLATE I. VOL. XX


Cauldwell
IPSWICH
Cliff
Greenwich Farm
Lower hearth Point
John's
Bowns
Reach
Town
Whinnyfield
Mulberry-

re in feet at Low water ordinary Spring tides.

line is shown thus ……………………………

line is shown thus ……………………………

SCALE

1 2 Statute Miles

TIDAL PHENOMENA of the RIVERS ORWELL and STOUR, at High Water of Spring Tides.

Place.	Distance above Harwich Junction.	Spring Range, or Rise above Low Water of Spring tides.[1]		Time of H. W. at Full and Change.		Resulting Velocity per Hour.
HARWICH HARBOUR.	Statute Miles.	Ft.	In.	H.	M.	
(Junction of the Orwell and Stour)	..	11	6	12	6	..
RIVER ORWELL.						
Pin Mill	5·4	11	11	12	20	23·1
Downham Reach	7·4	12	2	12	27	17·1
Dock Gates, Ipswich . . .	10·2	13	7	12	35	21·0
RIVER STOUR.						
Wrabness	6·0	12	2	12	29	15·65
Mistley Quay	9·8	11	10	12	48	12·0
Catawade Bridge, about one mile above Manningtree . .	12·0	4	3	1	8	6·6

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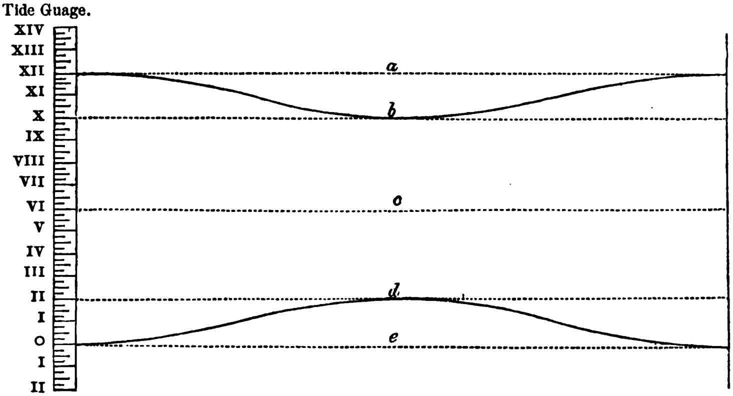
[1] The following diagram is intended to explain the terms, Spring Range, Spring Rise, Neap Rise, and Neap Range, made use of on the Admiralty Charts, and in the Sailing Directions published by the Admiralty :—



a = Mean Level of High-Water Ordinary Springs.
b = ,, ,, ,, Neaps.
c = Half-Tide, or Mean Level of the sea, both at Springs and Neaps.
d = Mean Level of Low-Water Ordinary Neaps.
e = ,, ,, ,, Springs.

EXAMPLE.

ft.
Spring Rise, or Mean Spring-Range = *e* to *a* = 12
Neap Rise . . . . . . = *e* to *b* = 10
Neap Range . . . . . = *d* to *b* = 8

Some of the above results, such as the greater velocity of the high-water portion of the tidal wave in the estuary of the Orwell, as compared with that in the Stour, and the increased velocity and range of the tidal wave in the upper part of the estuary of the Orwell, would, at first sight, appear anomalous; and if they had not agreed with similar tidal phenomena in certain other estuaries, where he had made the most complete investigations, he should have been inclined to have rejected them, as incorrect. But even with the limited information before the Institution, he considered they might be fairly attributed to the difference in the configuration of the two estuaries. As both estuaries were supplied by the same derivative tidal wave, through the common entrance of Harwich Harbour, he thought that if, at any future period, a more critical examination was made of their relative tidal phenomena, a striking illustration would be afforded of the fact, that the greatest development of the tidal wave was not dependent upon the area, or tidal space of an estuary, but upon its slope and the relative configuration and transverse section of its high and low-water channels; or in other words, not upon the expanse of waterway presented by the estuary to the tide at high water, but upon the successive mean depths, or heights of the tidal channel below, or above the mean water-level of the sea. As regarded the high-water channels, a reference to the published Admiralty Chart would show, that at the point of bifurcation, the high-water widths of the two estuaries were about equal. The Orwell, however, had what was usually called, a trumpet mouth. Its average high-water width was about half a mile, and notwithstanding some irregularities in its high-water outline, it might be said, in the upper part of its course, to taper gradually, until it reached Ipswich. The Stour, on the contrary, after passing the entrance gorge between Harwich and Shotley Point, where there was but little difference between the widths of its high and low-water channels, suddenly opened out its high-water margin to more than three-quarters of a mile in width, and at high water, the estuary formed a sort of elongated pouch of varying expanse, having its greatest width of upwards of a mile, at Holbrook Bay, about midway of the distance. The Stour was also, at high water, much broader, in proportion, towards its head, than the Orwell.

There was, also, a marked difference in the configuration of the low-water channels of the two estuaries, for although the 2-fathom line of soundings extended nearly the same distance, about seven miles up each, the low-water channel of the Orwell, at its entrance, was more shallow by 10 feet than that of the Stour; and it was also only half as wide. But these comparative defects were more than compensated for, by the circumstance, that the low-water channel, like that at high water, tapered gradually, in its course up to Ipswich. The operations described in the Paper, must also materially have reduced the slope of the low-water channel of the Orwell, towards its head. The low-water channel of the Stour, for the first five miles, up to Wrabness, besides being considerably broader and deeper than that of the Orwell, was also straighter; but beyond that point, it suddenly contracted its dimensions and assumed a comparatively narrow and winding course. The bed of the upper portion of the estuary of the Stour had also, no doubt, considerable slope, for while there was nearly 11¾ feet of spring range at Mistley, there was but little more than 4½ feet at Manningtree. The two estuaries might, therefore, be considered as presenting two entirely different types of configuration, and in summing up their relative capabilities as regarded the propagation of the tidal wave, he was of opinion, that the greater high-water expanse in the Stour was the cause that, notwithstanding the superiority of its low-water channel in the first five miles, the high-water portion of the tidal wave travelled in this estuary, with so much less velocity than it did in the Orwell. The greater velocity and increased range of the tidal wave in the upper part of the Orwell, he considered to be due to the opposite cause, to the tapering shape of the estuary, and the comparatively sudden stoppage and reduplication of the tidal wave at Ipswich. If the Author could place on the records of the Institution, sections of the two rivers, it would contribute greatly to the right understanding of their tidal régime; and as it had already been suggested, the great benefit which the port of Ipswich had derived from his labours, would also be better appreciated.

Great changes had taken place, from time to time, in the coast line at the mouth of Harwich Harbour, and in its vicinity, and there were certain points in the hydrological history of the locality, which were deserving of notice. The cliffs which had, originally, formed the determining, or more seaward projecting points of the coast, were chiefly composed of blue, or London clay, with layers of septaria, or cement stone, and he attributed the changes which had taken place, primarily to the inroads of the sea upon those cliffs, but more recently and immediately, to the excavation and removal of the cement stone from their base and frontage; and from the ledges of rocks which, extending to a great distance seaward, had previously formed a natural barrier, protecting the shore from the further action of the waves.

The shingle on this part of the coast travelled along the shore in a south-westerly direction, forming extensive beaches, except where it was diverted into deep water by the configuration of the coast, or the outfall scouring of a tidal river, or estuary. The sea had made great ravages upon the shore at Felixstow Point, the next determining point of the coast line, to the northward of the entrance of Harwich Harbour. The remains of an old castle which formerly stood on Felixstow Cliff, were now occasionally uncovered at low water, and the wasting away of this cliff and the partial removal of a massive ledge of cement stone from its frontage, had permitted the unobstructed passage of the shingle along the shore, and thereby, had, no doubt, contributed, in a great degree, to the extension of the tongue of shingle called Landguard Point, which formed the eastern boundary of Harwich Harbour. The south-westerly and in-shore extension of this tongue, and a similar extension of its under-water spit, together with the washing away of the shore, from time to time, on the opposite side of the entrance, had been, and were at present, matters of serious apprehension to all interested in the preservation of this valuable port and its dependent estuaries.

From an old map of England, it appeared, that the locality on which Landguard Fort now stood was, originally, an island, and that the harbour had, formerly, two entrances; the northern entrance, it might be assumed, had been closed up by the travelling shingle. Landguard Fort was built in the reign of James I., for the defence of the harbour. By an old picture, it appeared, that its site was then the extremity of Landguard Point. This picture showed the ground sloping from the fort to the water's edge, at the rate of about 2 to 1, and represented large square-rigged vessels, at a short distance from the shore, sailing into the harbour. The Admiralty Survey of 1804 showed, that the high-water margin of Landguard Point had then extended 480 feet from the fort in a southerly direction; and the entrance channel, at that period, had 7 fathoms opposite the end of the point. Little alteration appeared to have subsequently taken place, until after the traffic in cement stone had become one of considerable importance, or until about 1826. But after that period, from the continual removal of the cement stone from the foot and frontage of Beacon Cliff, on the western side of the harbour, the entrance channel widened out on that side, and in consequence, a large proportion of the flood and ebb streams, which had previously swept round the end of Landguard Point and Spit, passed in and out, to the westward of the Cliff Foot Rocks. The removal of the cement stone from Felixstow Ledge had been carried on, contemporaneously with that from the foot and frontage of Beacon Cliff, and thus Landguard Point, having an additional supply of shingle, with a less concentrated tidal scour to resist it, gradually advanced, closed up the deep-water channel, and reduced the available depth into the harbour, to 11 feet.

In 1843, Captain Washington, R.N., (Assoc. Inst. C.E.,) made an elaborate Report to the Admiralty on the subject, in which he stated, that "while the sea has gained on the western side of the harbour, the contrary has taken place on the eastern, or Suffolk side, where, within the last thirty years, Landguard Point has grown out 1,500 feet, thereby blocking up the chief entrance into the harbour; so that, where in the year 1804 was a channel, 7 fathoms deep at low water, there is now a shingle beach, as many feet above high-water mark." The Refuge and Tidal Harbour Commissioners subsequently directed the attention of the Government to the state of the entrance, and between 1847 and 1849, a stone breakwater, 508 yards in length, was run out from the foot of Beacon Cliff, with the object of restoring the scour of the tidal streams to the Landguard Point side of the entrance channel, and at the same time, extensive dredging operations were undertaken, and several shoals within Harwich Harbour, viz., the Altar, Cod, Glutton, Bone, Gristle, and Guard, were wholly, or in part, removed, so as to give a broad channel into the harbour, with a uniform depth of 18 feet at low water of spring tides. The cost of these works was £130,000. The following Table exhibited the progressive increase of Landguard Point from 1804 to 1859:—

Year	1804	1841	1846	1850	1852	1859
Distance from Landguard Fort, in ft.	480	1,890	2,065	2,265	2,265	2,650
Growth per annum, in feet . .		38	35	50	0	55

From the measurements in the Table, it appeared, that although the growth of the point was temporarily arrested between 1850 and 1852, yet during the last seven years, it had been increasing more rapidly than before. A comparison of the Admiralty Charts also showed, that the growth of the point had been accompanied with a corresponding under-water development of its base; and the present state of the entrance was such as to demand the most serious examination, with a view to remedial measures, by those who were intrusted with the duty of watching over the prospective capabilities of the port, which had emphatically, but justly, been described, as "the only Harbour of Refuge, properly so called, between the Humber and the Thames."

In reply to questions from Members, Mr. Curtis stated, that he had not the levels of low water, he had only the spring ranges of tide at the different localities, the times of high water at full and change, and the soundings from the Admiralty Survey. There was a greater vertical range of tide at Ipswich than at Harwich. The vertical range of tide was the working of the tide up and down, irrespective of its actual, or absolute level.

Mr. Peter Bruff observed, that Manningtree was very different from Mistley, which was the point where the main channel divided, and that, at the latter place, vessels of from 300 tons to 500 tons could go up, but at the former, there was water only for vessels of about 60 tons.

Mr. J. C. **Curtis** pointed out the relative position of each of those places, and the course of the low-water channel between them, but remarked, that he did not think the omission of this point of detail, would make any material difference as regarded the general view he had endeavoured to give, of the comparative configuration of the two estuaries.

Mr. W. A. **Brooks** inquired, whether the extraordinary elevation of tide at Ipswich, was not due to the forcing back of the land water by the sudden resistance to the progress of the tidal wave, occasioned by the rapid contraction of the channel.

Mr. **Hawksley** did not see any anomaly in the higher elevation of the tide at Ipswich, than at Harwich. There was an analogous instance in the case of the Severn, in which the rise of tide, at Chepstow, was from 48 feet to 60 feet, two, or three times greater than at the open sea, at the mouth of the river. Another well-known instance was that of the tides in the Bay of Fundy, where there was a rise of 120 feet, although the great tidal wave in the Atlantic, from which it proceeded, was only about 10 feet in height. He believed there was no well-founded theory, which explained that difference of elevation. To account for it, there should be a velocity of 80 feet per second, but the tide had no such velocity; and in the case of Ipswich, it was, in some degree, dependent, no doubt, upon the contraction of the river; but he was not acquainted with any mathematical solution of the problem.

Mr. **John Murray** remarked, that the phenomenon of the tide in the Bay of Fundy, had been explained by the Astronomer Royal, (Hon. M. Inst. C.E.,) in his treatise "On Tides and Waves."[1] The long indentation of the coast permitted the stream of flood coming from the Atlantic, to rise, not, as had been stated, 120 feet, but only from 60 feet to 70 feet. He had been told by the late Admiral Beaufort, that the exact rise had never been properly ascertained, but it was imagined to be about what he had mentioned. Professor Airy's theory was, that when an estuary contracted and shoaled rapidly, the range of tide would be increased to a considerable extent. At the entrance of the Bay of Fundy, the currents were very rapid, but the tidal range was only about 8 feet; while at the head of the estuary, where it branched into two shoaly arms, the range of tide sometimes amounted to 60 feet, or 70 feet. The time of high water was about an hour later, than at the entrance of the bay.

Mr. **Bidder**,—President,—said, that the Paper appeared to have been carefully prepared, and if it did not contain all the particulars that were desirable to be known, it contained a record of many useful facts. The discussion had diverged into the general question of rivers, and the action of tides, but such important issues could scarcely be taken upon so small a basis as the range of the present Paper. Upon the expiration of his term of office, he was fully determined, that an opportunity should be afforded for discussing that question, in a manner that its importance demanded. He differed from Mr. Hawksley, (M. Inst. C.E.,) upon the effect of land water; and he was quite prepared to contend, that land water, as regarded tidal streams and its action in maintaining the depth of the channel, was more injurious than beneficial. With regard to the question of tides, it was a most interesting fact, that in so small a length as twelve miles of a river, presenting so few remarkable features as the Orwell, there should be a difference of no less than 2 feet, in the rise and fall of the tide. It was desirable to have all the facts connected with that phenomenon recorded, for which purpose, it would be necessary to have cross sections of the river, between Harwich and Ipswich. The difference of level in the Thames, at the Nore and at London, was also about 2 feet, and yet the rise and fall of the tide was nearly the same at London Bridge, as at the Nore. He was not prepared to accept Professor Airy's theory of the physical results of the tides in the Bay of Fundy. It was well known, however, that waves did not rise to a very great height, from initiatory motion. But if an ordinary wave, of a few feet only in height, was hurried over places where the rocks gradually narrowed and became funnel-shaped, although there was no surface motion in the water, yet the wave might, by accumulation, be projected to a height of 30 feet, or 40 feet, in the crevices of the rocks. How far that observation was applicable to the theory, there were no data by which to determine. The Paper was a step in the right direction, but many more were required, before the Institution could fairly take up the great issue of the true theories of rivers, and of the action of tidal waves in estuaries.

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[1] *Vide* "Encyclopædia Metropolitana." London, 1848. Vol. v., p. 371.*

November 27, 1860.

JOHN HAWKSHAW, Vice-President,
in the Chair.

No. 1,030.—"On the Maintenance and Durability of Submarine Cables in Shallow Waters."[1] By WILLIAM HENRY PREECE, Assoc. Inst. C.E.

IN July, 1859, the late Mr. Robert Stephenson, at a meeting of the Electric and International Telegraph Company, over which he presided, made some remarks respecting the durability of submarine cables, which caused, at the time, much surprise and induced considerable controversy. He stated, that so far as his own experience and opinion went, no cable, over which he had any control, was sufficiently durable, to render it a satisfactory and remunerative speculation. He was supposed to apply these remarks to all submarine cables, and much valuable information was produced to controvert such a conclusion. It is not the intention of the Author to discuss the question at length. He will simply record his own practical experience in the maintenance and repair of a submarine cable; hoping, thereby, to lay a foundation, upon which a discussion can be raised, which will tend to the solution of this important point, and will prove beneficial to the profession, and serviceable to the progress of submarine telegraphy.

The cable alluded to, is that connecting the Channel Islands, Alderney, Guernsey, and Jersey, with England. These islands are situated in the Bay of Avranches, on the north-east portion of the coast of France. The nearest island, Alderney, is 57 miles from the coast of England, and 9 miles from that of France; Guernsey lies 18 miles from Alderney, and 17 miles from Jersey. These islands are accompanied by several smaller ones, and all are closely surrounded by a mass of jagged rocks. Their geographical position renders them peculiarly subject to the full force of the great westerly gales, which prevail during the winter months. The great rolling waves of the Atlantic, as they dash and break upon these wild and rocky shores, the disastrous wrecks that annually strew their coasts, the immense boulders thrown up and rolled about by the irresistible force of the disturbed waters, give some idea of the destructive action to which any submarine cable, landed on such shores, must be liable. Moreover, as these islands are situated in that portion of the Channel where the opposite coasts begin to form, as it were, a funnel for the entrance of the tidal wave, the tides and currents possess great force. The tide, which rises on the English side only 6 feet, here attains an altitude of 40 feet; the currents also, in several localities, acquire a velocity of 7 and 8 knots per hour. It will thus be seen, that the shores upon which it is landed, the bottom of the sea upon which it lies, the heavy tideways which it crosses, and the peculiar disturbances of nature to which it is liable, are all calculated to try, to the utmost extent, the qualifications, for permanency and durability, of any submarine cable, connecting these islands with the mainland.

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[1] The discussion upon this Paper extended over portions of five evenings, but an abstract of the whole is given consecutively.

This line of telegraph was projected by the islanders themselves. It is the property of a Company formed under the Limited Liability Act, with a capital of £30,000, upon which a conditional guarantee of 6 per cent. has been given by the Government. The contract for the whole undertaking was let to Messrs. Newall and Co., who submerged the cable, constructed the land lines, and handed over the whole telegraph complete, to the Company. The sample of the cable to be used was submitted to the Directors, but the selection of the route, and the manner of carrying out the work, was left entirely to the Contractors. The connection of the Author, as Engineer, only commenced after its completion by Messrs. Newall and Co.

The line starts from Weymouth, (Plate 2, Fig. 1,) crossing the Island of Portland by underground wires, and connecting that island with Alderney, by a submarine cable 57½ miles long. It crosses the Island of Alderney, and proceeds thence to Guernsey. After crossing Guernsey, underground, it is continued to Jersey, where it terminates at the town of St. Helier's. There is a station at each of these islands. The whole length of submarine cable submerged is 93¼ miles, and the length of the underground portion is 23 miles. The latter simply consists of a gutta-percha covered wire, coated with tarred yarn, and laid in a creosoted wooden trough, buried about 20 inches in the ground. The cable consists of two portions, the sea part, and the shore ends. The sea part is a No. 1 gutta-percha covered wire, served with tarred yarn, and protected by ten No. 6 iron wires; it weighs 2½ tons per mile. The shore ends are similar, but they are protected by ten No. 2 iron wires; they weigh 6 tons per mile. The cables were submerged by Mr. Newall, from the steamship 'Elba,' in August, 1858. When completed, the line tested perfectly, and being worked by an improved system of the Morse printing instrument, constructed by Messrs. Siemens and Halske, of Berlin, and slightly altered by the Author to suit the requirements of English manipulators and the English system, the circuit was admirable for rapidity and efficiency.

The line was opened to the public, on the 7th of September, 1858. On the 23rd of November following, the wire crossing the Smallmouth Sands between Portland Island and Weymouth, was broken, owing to the sand banks being washed away by a succession of severe easterly gales. This accident was speedily remedied by the submersion of a stouter cable, in a more secure position. The second accident took place on the 27th of January, 1859, on the coast of Jersey. The cable was landed upon this island, in a small sandy bay, bounded by precipitous cliffs, and strewn with jagged rocks. It was laid in a zigzag path between the rocks, and was led up the face of the cliff in split iron pipes. The gales that raged at this period, carried away a quantity of the sand upon which the cable lay; and the wash of the breakers tore the iron pipes from their fastenings. The cable being thus loosened, was beaten about upon the rocks, and it was speedily ruptured. As the fracture happened within the line of low-water spring-tide, temporary communication was soon made, by connecting the ends together with a stout chain, and attaching a gutta-percha wire along it. This gutta-percha wire had, however, to be renewed each tide, as the rocks soon wore it away. The communication was permanently restored in the following manner. A fresh piece of stout cable, weighing 7½ tons per mile, consisting of a portion of the Atlantic cable, served with hemp, and surrounded by ten No. 1 iron wires, was manufactured by Messrs. Glass, Elliot, and Co., and spliced on to the old cable, as far out as the tide would allow. This was laid in a straight course, between the rocks, up to the foot of the cliff. In sandy bays, if a cable is not laid perfectly tight and straight, it is sure to become loosened, and be liable to motion, and if it is allowed to scrape upon a hard rock, it must, eventually, give way. The greatest care is, therefore, requisite, in fixing the ends upon rocky shores. In this instance, the cable, from the spot where it first came in contact with the rocks, to its end in the iron testing-post, upon the top of the cliff, was served with spun yarn, saturated with tar, to protect it from detrimental exposure to the spray, and the atmosphere. Where it rested upon the rocks, it was, in addition, served with thick wire, well bound down, to protect it from abrasion, and to give it greater strength. The shore ends of the cable are thus stouter, and stronger than any hitherto made. It is scarcely possible to imagine, that any power in nature could ever exert sufficient force, to make an impression upon such a mail-clad rope; but the Author has seen it seriously injured after having been exposed, during six months, to the violent action of the waves, and constant inspection and attention are required, to prevent a second rupture. It was clamped in strong iron crutches, (Fig. 2,) leaded into the solid rock. Where it passed between two rocks, it was chained to ring bolts, leaded into the rocks, the chains being fixed to a bell-mouthed pipe constructed in two pieces, and fitting closely to the cable, as shown in Fig. 3. The crutches, though heavy, and well fixed, have, in more than one instance, become loosened, and the chains have broken, but the cable remains secure, and with careful attention, it will probably outlast the other portions.

As the landing-places on the south end of Guernsey, and on the western side of Alderney, are equally rough and precipitous, after the accident at Jersey, the shore ends at those places were also examined. At Guernsey, where the cable is landed in a bay similar to that at Jersey, it bore severe marks of attrition, and in one spot, it could not have lasted many days. The cable was straighter and tighter than at Jersey, for this was the end from which the vessel started in paying out, and consequently, a strain was placed upon the rope. It was protected, strengthened, and fixed, as at Jersey.

The most exposed landing-place is, undoubtedly, that at Alderney. The cable stretches through a series of rocks, lying about half a mile off the shore. It is landed in a small bay, having a sandy bottom, and lofty rocky sides, surrounded by perpendicular cliffs several hundred feet high, up which the cable is taken. It was a hazardous undertaking to attempt the descent of these cliffs, but the Author and two other persons succeeded in accomplishing the task, by the assistance of the cable. It was found, where it lay among the rocks, loose, bent, and injured to an alarming extent. One mass of stone had fallen upon it, and perfectly flattened the iron covering. It was protected, strengthened, and fixed, in the same way as at Jersey and Guernsey. In doing this, the cable had to be cut on the beach, and hauled up to the top of the cliff, while a temporary wire maintained the communication uninterrupted. It has not yet shown any symptoms of decay, which is so far fortunate, as the operation of repairing it would be difficult. It has, probably, fallen between the rocks, and has thus been protected, instead of being destroyed by them.

The next interruption to which the line was subjected, took place off Portland Island, on the 19th of April, in the same year. In paying out this portion of the cable, Messrs. Newall started from Alderney, rather late in the day, and did not succeed in making Portland Island until night. In consequence, the landmarks were missed, or mistaken, and thus the Portland Race was crossed with the cable. The tidal current, when unobstructed, flows, generally, in the English Channel at from 3 knots to 4 knots per hour, but in Portland Race it runs at the rate of 8 knots and 9 knots. The rapid passage of waters extending to the bottom of the sea, not only affects the placidity of the surface, but scours, roughens, and ploughs up the ground below. The bottom, as far as the Race extends, is extremely rough and rocky. A cable, resting on such a surface, must, necessarily, be very insecure, and so it proved, for on the 19th of April, the cable parted at the distance of 3¾ miles from the shore, having been completely severed by abrasion upon the sharp edge of a rock.

All previous accidents at sea to submarine cables, which have come within the Author's knowledge, have been the result of accidents from well-known causes. Ships have either dragged their anchors across a cable, too weak to sustain the strain suddenly placed upon it, or the cable has been brought to the surface, and then wilfully, or accidentally cut. But in this instance the cable was broken, in the short space of six months, by the operation of the great forces of nature. Fig. 4 will explain the probable cause of this accident. When a rope is stretched across a current of water, a quivering motion may be observed. The rush of the tide would give a cable, laid in the position shown, a similar vibration, which would make the rock act like a file, and the iron coating of the cable would be rapidly abraded. The outer iron wires bear distinct marks of this abrasion, and the ends have been worn down to a small diameter. The cable was, evidently, laid so tight, that the instant a few wires had been worn through, the remaining wires, together with the gutta-percha wire, were too weak to bear the strain, and were, consequently, broken. The cable was picked up from the shore, considerably beyond the break, in the hope of removing it from the rough ground, and it was relaid further to the eastward. The original and the present course of the cable are shown upon the chart; (Fig. 1.) A new cable, of larger dimensions, was submerged across the portion of the original ground, which could not, without great expense, be avoided. In repairing this cable, several places were picked out, where this same action had commenced. The first mile from the shore, with the exception of the existence of two bad 'kinks,' was in excellent condition, showing no signs of decay, or wear, and lying undisturbed at the bottom of the sea. The rest of it, however, which lay through the Race, was much decayed, not only by friction upon the rocks, but by rapid oxidation. Shoals of mussels, zoophytes, and rank vegetation were found, clustering on the wire.

The communication was restored on the 18th of May. Much time was occupied in the repairs, owing to the unpropitious state of the weather. This is not of material consequence in paying out a cable, except in the operation of landing the ends, but in repairing cables, it is essential, that the weather be fine, and the sea comparatively calm. During the month occupied in these repairs, only four days occurred which were at all suitable for carrying on the operations.

In picking up the last portion of the cable, a stone, about 1 foot square, and 3 inches thick, came up attached to it. Across this stone there was a groove, bearing an exact impression of the cable, which appears to the Author to have gradually, by some chemical action, made a bed in the stone. Its substance differs from any stone found in the neighbourhood of Portland Island.

The line continued in excellent working order, during the whole of the ensuing summer, but in September, a serious fracture occurred off Jersey, and in November, another off the Island of Portland. In the latter case the cable was broken in two places, at 6¾ miles, and at nearly 12 miles from the shore; each fault was precisely similar in character to that previously described. Off Jersey, the cable became defective on the 16th of September, and the accident was also of the same nature. All the previous fractures had taken place without warning. In one instance, during the transmission of an important message, and while the line was in good working order, the communication was suddenly interrupted. In this case, however, symptoms of failing strength early displayed themselves, and for several weeks, the cable had been working indifferently. A serious defect showed itself in the cable between Guernsey and Jersey, at some spot not far from the Jersey shore, and gave intimation of rapid decay. At last, the communication ceased, and steps were taken to repair the cable. Three faults were discovered within a length of half a mile, two were due to 'kinks,' and the other to abrasion, the last being the cause of the cessation of the communication. The cases of abrasion previously explained, occurred in the smaller-sized sea portion of the cable; but this took place in the heavy shore end. The outer wires, with the exception of one, were completely worn through, the gutta percha was nearly destroyed, and the interior copper conductor had been completely abraded. The cable had, no doubt, been resting on the edge of a rock, and had been sawn through by the vibratory movement given to it by the tide. The 'kinks' were made, when the cable was laid down; the gutta percha had been forced out, causing two considerable faults, which would inevitably, before long, have stopped the communication. Kinks are frequently caused in the operations of repairing, when picking up a cable, but it is very easy to distinguish a kink, made in laying down a cable, from one made in repairing. The one shows signs of oxidation and age, the tar of the serving is washed away, and the gutta percha is frequently visible; the other looks fresh, and of very recent formation. Kinks are not, as a rule, of serious consequence, unless the cable is laid on rough ground, or in a heavy tideway; but on such a line as that to Jersey, they are fatal. Only four kinks have been discovered, which must be considered as highly creditable to the Contractor; but the same praise cannot be awarded for the manner in which the end was landed in Jersey. This is the most difficult operation connected with the submersion of cables, and that which requires the greatest care and skill. When once the cable has been started, there is little, or no difficulty in paying out. Attention and care are only required, to see that every part of the machinery works well. But when the landing-place is approached, the coast, the depth of water, the weather, and the tides, have to be consulted. If the coast is rugged, care must be taken to avoid the rocks; if the water is shallow, the ship must be kept off the ground; if the weather is boisterous, the end must be cut, dropped, and buoyed, and the operation completed upon a more favourable occasion; and if the tides run fast, care must be taken to allow for their effect upon the ship, and to steer her course accordingly. At certain times of the tide, a sharp current runs past Cape Grosnez, near which the cable is landed, and the pilot in charge of the 'Elba' evidently overlooked this, for the cable, in place of taking a straight course into the bay, is laid as is shown in the chart; (Fig. 1.) It thus crosses some rocky ground, which might have been avoided, if proper allowance had been made for the current. It was upon this rocky ground, that the cable failed: it seems, moreover, to have been thrown out loosely, for it was lying zigzag in considerable bends, and a length of half a mile of cable was afterwards saved, by laying it straight; (Fig. 1.)

The cable was again broken on the 9th of January, 1860. The same kind of accidents which had occurred off Portland, were repeated off Alderney, and the cable was severed by the rocks, at a distance of 6 miles from that island. It was in precisely the same condition, abraded and decayed, so much so, that it was broken in picking up. Five miles of new cable, of a superior description, were submerged; it was a piece of the Atlantic cable, strengthened with ten No. 6 iron wires, similar to the excellent cable which the Submarine Company have laid between Jersey and the French coast. The cable subsequently failed in September last, at the same place and from the same cause. It has also been broken three times off the coast of Jersey, from having been accidentally caught by ships' anchors. The following Table gives a list of all the accidents that have occurred up to the present time:—

TABLE I. FRACTURES.—CHANNEL ISLANDS CABLE.

No.	Date of Rupture.	Position.	Distance in miles.		Depth of Water.	Nature of Fault.	Ship employed for Repairs.	Duration of Fracture.
			Actual.	By Test.				
					Fms.			Days.
1	Nov. 23, 1858	Smallmouth Sands.	..	..	..	Washed away by sea.	..	2
2	Jan. 26, 1859	Off Jersey .	On shore.			Abrasion .	..	3
3	Apr. 19, 1859	Off Portland	$3\frac{3}{4}$	3	22	,, .	Prince .	26
4	Sept. 17, 1859	Off Jersey .	$\frac{3}{4}$	$1\frac{1}{2}$	17	,, .	True Briton	19
5	Nov. 1, 1859	Off Portland[1]	$6\frac{3}{4}$	$5\frac{1}{2}$	27	,, .	Monarch .	22
6	Jan. 9, 1860	Off Alderney	6	6	35	,, .	Resolute .	26
7	Feb. 25, 1860	Off Jersey .	$3\frac{1}{4}$	3	23	Caught by ship's anchor	Contractor	14
8	June 7, 1860	,, ,, .	$2\frac{2}{3}$	$2\frac{2}{3}$	21	,, ,,	Dumfries .	12
9	July 19, 1860	,, ,, .	5	$4\frac{1}{2}$	26	,, ,,	,, .	13
10	Sept. 16, 1860	Off Alderney	7	$7\frac{1}{2}$	40	Abrasion .	Monarch .	10
11	Sept. 18, 1860	Off Jersey[2] .	$17\frac{1}{4}$	$16\frac{11}{14}$	25	Caught by ship's anchor	,, .	11

[1] Broken also 12 miles off the land.

[2] Tested from Guernsey.

It will be seen, that since the submersion of the cable, in August, 1858, it has been ruptured in eleven different places. Two of these accidents were the result of carelessness, or negligence, in landing the end of the cable on the Jersey shore. Four were caused by ships dragging their anchors, and five were produced by the action of the rocky bottom upon the slender wire. The accidents arising from ships' anchors all took place between Jersey and Guernsey. Those resulting from abrasion, occurred between Alderney and Portland. Between Guernsey and Alderney the cable has never failed. The constant interruptions of this line are attributable, the Author believes, to two causes, weakness of cable, and error of judgment in the selection of the route. The cable should never have been laid between Guernsey and Jersey, but from Jersey to Alderney. It not only crosses ground, where ships are frequently in the habit of anchoring, but also, in a portion of its route, it lies upon a rough uneven bottom, swept by strong tides. A stouter cable might lessen the liability to accidents from the first cause; while by a détour to the westward, this rocky ground would be avoided. But by carrying the wire from Jersey to Alderney, neither danger would be encountered. There is no anchorage along that route, and the ground is smooth and free from rocks, except on the immediate shores of the island. This route was the first selected, but it was objected to by the Government, on account of its proximity to the French coast. In the event of a new cable being laid, this route will be adopted. Neither should the cable have been laid between Alderney and Portland, but from Alderney to the Isle of Wight. The bottom here, excepting immediately outside Alderney, is smooth and soft, the whole way across; the run of the tides is not so great; the shores of the Isle of Wight are devoid of rocks; and ships never anchor on any portion of the route. The distance is, certainly, greater, but the liability to accident from every cause, is considerably less. It must, however, be stated, in justice to those who decided on the route adopted, that reliance was, perhaps, unfortunately placed on the Admiralty Charts, which the Author has never found to be correct in describing the nature of the bottom. They truly represent the depth of water, and the currents, but they as frequently show rocks where sand is found, and sand and gravel where there are rocks. This is especially the case off Portland, where ledges of rocks, of which no intimation is given on the charts, extend 15 miles, or 20 miles out to sea. A cable should never be trusted to the unseen and unknown action of the bottom of the sea, without its course having first been carefully surveyed and examined.

The Channel Islands cable is also too weak for the locality in which it is placed. It cannot resist the strain of a heavy ship, nor can it, for any length of time, withstand abrasion from a rock. The run of the tides, and the decomposing action of the water upon such a small cable will, eventually, and indeed very shortly, so weaken and corrode it, that the expense and difficulty of repairing it will be very much increased. The chief defect, however, in the system, cannot be said to be so much in the cable used, as in the route selected.

In conducting the repairs of this cable, it was curious to observe the effect of the water, in different localities, in oxidising the outside covering. In places where the cable had become slightly buried in the sand, it was as perfect as when it was first laid. On rocky ground, where it was swept by the tides, it was being rapidly corroded, and where vegetation and zoophytes adhered to the cable, patches of decay were visible. The Author is of opinion, that in localities where a cable cannot bury itself, it must speedily be destroyed by oxidation, and that the period of its durability will solely depend upon its size. In such places, some outer protection to the iron wire is necessary. Mr. Latimer Clark, (Assoc. Inst. C.E.,) has devised a method of applying hemp saturated with asphalte, on the outside of the iron wires; and it was applied to the Isle of Man cable. This plan, though promising, is liable to cause injury to the inside wires, through the necessity of applying the asphalte at a high temperature. But there should be no difficulty in discovering an equally effective material, which may be used cold. The Report of Mr. Cromwell Varley,[1] on the attempted repairs to the Atlantic cable, off Newfoundland, described the state of preservation in which the wire was found, wherever it was coated with hemp. No cable should ever be submerged in shallow waters, without some exterior protecting coating, to preserve it from oxidation.

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[1] *Vide* "The Engineer," July 27, 1860.

The Channel Islands cable was also laid much too tight; wherever a break has occurred, through abrasion, it has been observed, that after six, or seven wires have been worn through, the rest, with the gutta-percha wire, have parted, being unequal to bear the strain. Cables in shallow water should be laid slack, and be payed out with only sufficient strain, to make them take the sinuosities of the ground, without falling into bends and kinks. Moreover, the slacker they are laid, the easier they are to repair, and repairs must be anticipated and provided for, in all submarine cables. Figs. 4 and 5 exhibit the difference between a cable laid tight and a cable laid slack.

In designing a cable, its durability and maintenance, points at present almost altogether overlooked, should be primarily considered. The present construction of heavy cables is believed by the Author to be defective. These cables depend for weight and strength, on a number of large-sized iron wires, surrounding the insulated conductors. When these outer iron wires are what is technically called 'short,' they break in running over the break drums. If ships accidentally catch the cable, the wires are also broken, and the surging of the anchor along the rope rapidly increases the evil by 'rucking' them up. The outer wires should, in the Author's opinion, either be stranded, or the cable should be surrounded with two servings of smaller-sized wire. The Atlantic cable is, on a small scale, an example of the first, and the Jersey and France cable, of the second.[1]

It follows, from what has been said, that in establishing a submarine telegraph for crossing shallow waters, experience has shown, that the Engineer should, first, select a proper route, and secondly, that he should design a cable suitable for that route. He should vary the construction of the cable, according to the nature of the ground to be crossed, as it would be absurd to lay a heavy cable intended to resist anchorage, over soft ground, not frequented by ships. In regard to the route, it would, frequently, be more economical to make a détour of fifty miles, in connecting two points by a submarine telegraph, than to take the straight line.

The system which the Author has adopted in conducting his repairs, is analogous to that originated by Mr. F. C. Webb, (Assoc. Inst. C.E.,) in repairing the cables in the North Sea, belonging to the Electric and International Telegraph Company, and described by him in his Paper, read before the Institution, in 1858.[1] Having, by a system of careful tests, determined the position of the fault, a steamer was fitted up for the purpose of grappling the cable, as close to the fault as its position, and the nature of the ground would allow. The cable, when raised, was cut, and the end which was perfect between the ship and the shore, was carefully buoyed. The portion of the cable leading towards the fault was then picked up, and was coiled down until the fault came on board. The other end was then grappled for, and when secured, a fresh piece of cable was spliced to it, and payed out to the buoyed end, to which it was also spliced, and the communication was thus restored.

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[1] The Electric and International Telegraph Company have adopted this suggestion, in their new cable to Holland.—Author. February, 1862.

The operation of grappling, picking up, buoying, and paying out, having been already described in the Paper alluded to, the Author will confine himself to a description of the system adopted by him, in testing cables.

There is no operation connected with the submersion and repair of submarine cables, which requires greater skill, more experience, and a more intimate knowledge of the laws that regulate that subtle force, electricity, than testing. It qualifies the Engineer to become thoroughly acquainted with the electrical condition of the wire from end to end, permitting him to glance, as it were, along the rope, however deep it may be submerged, to learn its imperfections, and to know its condition. It enables him to direct his ship with almost unerring accuracy, to the spot where any failure exists. It gives him a confidence in his operations, which astonishes the uninitiated, and pleases the men employed under him, and it considerably reduces the expense of repairing cables. To give an idea of the accuracy with which testing can be conducted, it may be mentioned, that on one occasion, the Author pronounced a fault, (No. 6 of Table I., page 33,) to be at 6 miles from Alderney, and that $2\frac{1}{4}$ inches of copper were exposed to the action of the salt water. The fault was ascertained to be exactly 6 miles off, and 2 inches of copper were found to be exposed. He has never been more than one mile wrong in his calculations, although the tests have been made at 5 miles, at 20 miles, and sometimes, at 30 miles from the broken end. Messrs. C. F. Varley and G. Preece, have been equally accurate in the North Sea. On one occasion, Mr. Varley pronounced a defect in the Zandvoort cable of the Electric and International Telegraph Company, to be 61 miles from the English shore, and it proved to be at the exact spot indicated. Mr. G. Preece, in testing on board ship, 13 miles from land, while repairing a break at that spot, found the cable again severed at a distance, according to his tests, of 50 miles towards Holland, and the break was found at $50\frac{1}{4}$ miles.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xvii., page 262.

Mr. Webb, in his Paper, has referred to and described his system of testing, but considerable improvement in the instruments used, and the manipulation required has been effected since that period. The study of testing has been generally neglected, in the education of telegraphists, and little care has been taken by the companies, to keep a careful register of the electrical condition of their cables and lines.

The principles employed in testing may be divided into those dependent upon the laws of resistance, and those dependent upon the laws of induction. Resistance is the obstruction which materials offer to the free passage of electricity, and it may be said to represent both conduction and insulation. A perfect conductor is one which offers no resistance to the transmission of an electric current; a perfect insulator is one whose resistance to the passage of the same current is infinite. No absolutely perfect conductors and perfect insulators, however, are as yet known; and thus the perfection of an insulator, or a conductor, depends, at present, upon its amount of resistance. If a wire conducts badly, its resistance is great, and if an insulator conducts well, its resistance is slight. It is, therefore, easy to express the degree of insulation, or conduction of a substance, in units of resistance; and this is frequently done in practice. It has been usual, hitherto, in describing the condition of a wire, or cable, to say, that it gives a° of earth, with n number of cells; that is, that a current being applied to one end of a wire, and the other end being disconnected, its imperfect insulation, or faulty places, allowed a° of current to flow to the earth, through a galvanometer. This a° is supposed to represent the insulation of the wire. It gives an approximate idea of the condition of the wire to the electrician who manipulates his own instrument, but to convey to others the state that a° represents, it is necessary to describe the instrument employed, the power used, and various other complicated details of construction and design. Every electrician must reduce this quantity to the standard of his own instrument. It will be subsequently seen, that it is easy to reduce to one universal standard, the insulation and condition of every wire and cable, in existence, or under construction.

The basis of all resistance tests, is the fundamental law of Ohm, which is expressed by the formula:—

$$R = \frac{L\,C}{S},$$

where R = the resistance;
L = the length of wire;
C = the specific resistance of the material employed;
S = its sectional area.

The specific resistance of different metallic bodies (C), varies considerably, as will be seen from the following relative conducting powers of different metals, according to Becquerel:—

Copper	100	Platinum	16·4
Gold	93·6	Iron	15·5
Silver	73·6	Mercury	3·45
Zinc	28·5		

The relative conducting powers of iron and copper, which are the materials usually employed for telegraphic purposes, are, consequently, as 15·5 to 100, or as 1 to 6·45 nearly.

The resistance of a wire is directly as its length (L), and inversely as its sectional area (S). If A B represents a copper wire 1 mile in length, and C D one 10 miles in length, both being of the same dimensions and material, the resistance of C D will be exactly ten times that of A B; but if the sectional area of A B is reduced to one-tenth, then the resistance of A B will exactly equal that of C D. Again, if the wire A B is made of iron instead of copper, the same dimensions being retained, the resistance of A B will be six and a half times greater than that of C D. If now, A B is reduced to six and a half times its length, its resistance will again equal that of C D. Thus a short length of fine iron wire, will offer the same resistance to the passage of an electric current, as a long length of ordinary-sized copper wire, and will produce the same phenomena. One mile of No. 40 iron wire offers the same resistance as about five hundred miles of No. 16 copper wire. Short lengths of this iron wire, are cut to represent any separate lengths of copper wire of the usual dimensions, and are wound round bobbins, forming a series of what are called, 'resistance coils.' They can be made to represent any length of cable, but the series usually constructed consists of two hundred and twenty-one miles of No. 16 copper wire. By these means, the resistance of any cable can be ascertained, it being only necessary to compare the resistance of the material of which it is made, with that of No. 16 copper wire. Thus the resistance of the Channel Islands cable is to that of No. 16 copper wire, as 36 to 17; consequently, 17 miles on the Author's resistance coils are equal to 36 miles of the Channel Islands cable. In the case of the Gibraltar cable, 1 mile on these coils would represent 8 miles of that cable.

The coils, used by the Author, are constructed by Mr. Cromwell Varley, and the standard employed is one mile of the No. 16 copper wire, which was in use four, or five years ago. The quality of copper, however, owing to the presence of alloys and other imperfections, varies considerably, and its resistance differs accordingly. The best selected copper varies as much as 20 per cent.

in its conductivity, and the purer it is the better it conducts. Even annealing makes a difference; annealed copper wire conducts 2·5 per cent. better than that which is hand-drawn. This subject has been carefully investigated by Dr. Matthiessen, and the results were communicated to the Royal Society in a Paper, "On the Electric Conducting Power of Alloys."[1] In the copper wire supplied to the Atlantic Telegraph Company, some lengths varied as much as 40 per cent. The attention of the Gutta Percha Company having been called to this fact, a considerable improvement in the quality of copper supplied, has been the result; every mile of copper as it enters the works, is now carefully tested by the Company. The No. 16 copper wire of the present day, conducts better than that of the standard used, in the proportion of 3 to 2. The old standard is, however, adhered to, and it is only necessary to obtain the ratio between it, and the wire under examination, to obtain the relative resistance. Messrs. Siemens, Halske, and Co., of Berlin, employ a different standard. Their unit of resistance is a column of mercury, one mètre in length, and one square millimètre in sectional area, taken at the freezing point of water. Professor Wheatstone's standard of resistance is one English foot of copper wire, 0·071 inch in diameter, and intermediate to Nos. 15 and 16. But these standards can easily be applied to that used by the Author, by employing the proper ratio to reduce one to the other. The Author's resistance coils can only directly represent 221 miles of No. 16 copper wire, or 1,768 miles of the Gibraltar cable, but by the instruments employed, and the systems adopted in comparing the relative resistance of the coils and cable, they can be made to represent any resistance from unity to infinity.

The instrument usually employed, in comparing the resistance of two wires, is the common differential galvanometer of Becquerel, shown, at G, in Fig. 7. Two wires of equal length, and equal resistance, are wound round a magnet in the usual manner. One current passes along one wire, round the needle in one direction; the other current proceeds round the needle, through the other wire, in the opposite direction. When the two currents are exactly equal, or when the resistance of one wire is equal to that of the other, the needle is neutralised, and it remains at zero.

Another arrangement is that generally known as Wheatstone's parallelogram, shown in Fig. 6. A simple galvanometer is placed in circuit between B and C. When the resistance of A B is equal to that of A C, the needle remains at zero, but any inequality in the resistance affects the galvanometer.

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[1] *Vide* Phil. Trans. 1860, p. 161.

The Author has modified the common differential galvanometer, by which many useful and practical results can be obtained. It is a simple differential galvanometer, G, (Fig. 7,) and if connected up as represented, without W and P, it will show, that the resistance of R R′ will exactly represent that of D D′; but if a coil P, called a 'derived circuit,' is inserted between A and A′, so that its resistance is to that of half the coil, as 1 to 10, it will be obvious, that when the current divides itself between the two wires of the galvanometer, the whole of one-half will go through B B′, but only one-tenth of the other half through AA′; consequently, the current passing through the first half, will be ten times greater than that passing through the other half. Now, if the resistance of R R′ is reduced in the same proportion, it follows, that 1 mile of resistance in R R′, will exactly balance 10 miles of resistance in D D′; consequently, the ordinary coils can be made to represent any resistance from 1 mile to 2,210 miles. By reversing the position of the coils and the cable under examination, tests of short distances can be obtained to decimals of units. Thus the coils can be made to represent any length from $\frac{1}{10}$th of a mile to 2,210 miles. By making the resistance of the coil P, so that its resistance to G bears the same proportion as the relative resistance of the standard coils to the cable under examination, the length of cable being tested, can be read off, at once, on the coils, without the necessity of any calculation. With a coil, whose resistance is to that of half the coil of the differential galvanometer, as 36 to 17, the Author is able to read off his own standard coils, the length of the Channel Islands wire under test. The resistance of his galvanometer is 20 miles, consequently, the resistance of half is 10. Now with a set of coils, giving a resistance up to 10 miles, and a Wheatstone's rheostat, whose total resistance is equal to 1 mile, he can obtain any ratio from equality to infinity. In practice, however, it is found, that the effects of temperature, and the heating properties of currents, traversing short lengths of wire, produce such variable results, that a greater proportion between the two coils than 1 to 10, is scarcely admissible.

The proportions named are not strictly those employed in practice, nor are they correct in theory, because some allowance must be made for the reduced resistance of the galvanometer. To render them correct, additional resistance must be inserted at W, to make the combined resistance of the derived circuit, and the differential half, equal to that of the other half. But the Author has found it more convenient to obtain experimentally, that proportionate resistance between the two coils which will give the requisite multiplying power, without the necessity of employing additional compensating resistance coils. This instrument he calls the 'multiplying differential galvanometer.' It is not, however, advisable to attempt very high resistances with the multiplying differential, as the heavy power required might damage the coils. When the resistance exceeds 1,500 miles, the Author prefers reading off the resistance from the deflection of a delicate galvanometer. The plan he adopts is the following. He observes, on a delicate galvanometer, (Fig. 8,) the deflection of the needle, reducing, or increasing the power until the deflection amounts to 30°. He then inserts a known resistance, say 500 miles, at A B, and by the use of the derived circuit, D, reduces the deflection of the needle, until it reads the same as before; the power remaining the same. The ratio between the resistance of the derived circuit, and that of the coil, will give the ratio between the known and the unknown resistance. The same effect can be produced, by altering the battery powers to obtain the same reading on the coils and the wire. Thus, if with one cell, the galvanometer shows a° through 10 miles of resistance, and the same with one hundred and twenty cells through the wire, then:—

$$(10 + r \text{ of galvanometer})\ 120 = \text{Resistance of wire.}$$

It will now be seen how simple it is to express, in units of resistance, the state of the insulation and condition of a wire. If a wire, when submerged, represents upon the coils the exact resistance of its length, it insulates, and conducts well, and it is very perfect. If it gives a resistance less than its proper standard, there is a leakage, or fault, and if it gives a greater resistance than its proper standard, there is a bad joint, or imperfect continuity. If the end is disconnected, the leakage, or loss of insulation can be measured,—by the coils direct, if the loss is great,—and by the multiplying differential, or simple galvanometer, if the loss is slight. If the cable is broken at any spot, say at D′, (Fig. 7,) the resistance of D D′, or in other words, the distance of D′ from D, is shown upon the coils R R′. Thus in testing, from the office in Jersey, for the break marked No. 8 in Table I., (page 33,) the coils R R′ showed the resistance of D D′ to be 10⅔ miles, which placed the fault 2⅔ miles from the Jersey shore, at which spot it was found. Cables should be carefully tested by such processes, not only when laid down, and at work, but also during their construction and submersion. The Engineer in charge, would thus always possess a complete knowledge of the electrical qualifications of the cable. Had the Atlantic and Red Sea cables been so treated, the present condition and prospects of submarine telegraphy would have been considerably better.

The laws of induction are much more intricate than those of resistance. Electricity develops itself in two forms, dynamic and static. A dynamic current is a very different phenomenon from a static charge. A flash of lightning cannot be compared to the gentle current, generated by the tongue, between a shilling and a penny-piece; but they are one and the same thing under different forms. A thunder cloud can be dissipated as a dynamic current, and a dynamic current can be developed into a thunder cloud. Conduction performs the first, induction the last operation.

The insulated conductor of a submarine cable is a Leyden jar, of which the wire is the inside, and the outer iron wire, the earth, or the sea, the outside coating. Before this Leyden jar can conduct a current, its whole surface must be charged statically, by induction. When a current is thrown into a wire, its first influence is absorbed, as it were, in raising the surface of the conductor to a certain static tension, where it remains latent as long as a current flows through the conductor. But immediately the current ceases, and the end of the wire is placed to earth, the static charge flows out of the conductor at both ends, as a dynamic current. It matters not whether the end be to earth, or be disconnected, the phenomenon is the same in effect, though different in degree. If only one end is placed to earth, the other being disconnected, the whole charge flows out at that end. If both ends are to earth, the discharge is divided between the two. It is for this reason, that, in passing a current through a long submarine cable, it takes an appreciable period before it appears at the distant end, and when the current is stopped, it continues to flow out at that end, for some time after contact has been broken, while at the same time, another current of the same duration flows out at the near end; hence the speed of signalling through long cables is reduced.

The first rush of electricity into an open wire, is called the 'charge.' Its return, when the end is disconnected, is termed the 'discharge.' The current flowing out at the near end, when the distant end is to earth, is the 'return current.' The delay of the appearance of the current at the distant end, is its 'retardation.' The drawing out, or lengthening, of the current as it appears at the distant end, is its 'prolongation.' These different properties have, each, their own independent laws, and have recently received full examination and development; but as the testing, and not the working of submarine cables is now under consideration, the Author will abandon the inquiry into those laws affecting retardation and prolongation, and apply himself strictly to the charge, the discharge, and the return current.

The charge and discharge obey the same laws; the one is only a reflection of the other. Whatever, therefore, is said respecting the charge, is strictly applicable to the discharge. The return current is simply a modification of the discharge.

Now the charge of a wire depends:—

1st. Upon the distance between the inside and the outside coatings, the ratio of which is expressed by—d[1].
2nd. Upon the specific inductive capacity of the insulating medium—s.
3rd. Upon the surface of wire exposed to induction—S.
4th. Upon the length, or resistance of the conductor—R.
5th. Upon the power of the battery—n.

The law which regulates it may be expressed by the formula:—

$$C = \frac{n\,S\,R\,s}{d}.$$

But as all induction tests in submarine cables are, simply, comparative effects between certain phenomena, upon known and unknown lengths of the same wire, the consideration of the thickness and inductive capacity of the insulating medium may be discarded, and attention be alone directed to the surface exposed, the length of wire under examination, and the power of the battery used. The formula therefore becomes:—

$$C = n\,S\,R = n\,l,$$

when S and R remain equal, l being the length of wire.

Thus if it is desired to compare the charges of two separate wires:—

$$C : C' :: n\,l : n'\,l'$$

or, when the same power is used in each case:—

$$C : C' :: l : l'$$

and, if the lengths of the cable are the same:—

$$C : C' :: n : n'$$

From these proportions it follows, that, if a wire 10 miles long, gives a discharge of 10°, with one hundred cells, it will give 20° with two hundred cells, or 5° with fifty cells; and, if the power remains the same, it will give 5° with 5 miles, and 20° with 20 miles. Hence, if the discharge of any unit length of wire is known, the length of wire under manipulation can easily be calculated, by the above proportion. An example may be interesting, and more explicit. The cable between Guernsey and

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[1] This ratio (d) is expressed by Professor Thomson[a] thus: 2 log. $\frac{D'}{D}$; where D is the diameter of the wire; D', the diameter of the insulating medium; and log. the Napierian logarithm. Professor Wheatstone's ratio[b] is, $\sqrt{\frac{r}{t}}$; where r is the radius of the wire; and t, the thickness of the coating.

[a] *Vide* "Report of the Joint Committee appointed to Inquire into the Construction of Submarine Telegraph Cables." Folio. London, 1861. Minutes of Evidence, p. 126.

[b] *Ibid.*, p. 281, *et seq.*

Jersey was recently broken, the ends being completely disconnected, and it was tested from Guernsey. Between Guernsey and Alderney, $23\frac{1}{2}$ miles, thirty-six cells gave 28°; from Guernsey to the fault, the same power gave 20°:—

$$\therefore 28 : 20 :: 23\tfrac{1}{2} : 16\tfrac{11}{14}$$

The actual fault was $17\frac{1}{4}$ miles off, being an error of scarcely half a mile in the test.

The return current differs from the discharge, in name only. The term 'discharge,' is simply applied to the return current, when the distant end of the wire is disconnected. The term 'return current,' is applied to the discharge when the end is to earth, or when resistance is interposed between the end and the earth. The discharge formula becomes:—

$$C = \frac{n\,l\,r}{a},$$

a being a co-efficient depending upon the length of wire, and the time that elapses between the breaking and making contact, whence it follows that, as the resistance of the end r is increased, the return current is also increased, until r is infinite, when the return current equals the discharge. The converse of this would occur, when the resistance lies between the submerged wire and the testing place, but as in practice it is always possible, and indeed essential, before commencing operations, to make the tests at one end of the cable, this question need scarcely be examined.

The instrument, which the Author employs for the purpose of measuring and registering the discharge, is either a vertical galvanometer of great delicacy, or a peculiar arrangement of his own design, called a 'reduction inductometer.' With short lengths of wire, and low power, the simple galvanometer gives very true results up to 30°, when applied to the formula:—

$$C : C' :: n\,l : n'\,l'$$

the discharge being registered by the swing of the needle. But for longer lengths, the following plan is used. A, (Fig. 9,) is a simple galvanometer, through which the discharge flows to earth. Now if a unit length, say 1 mile, of submerged wire, gives 30° of deflection with n cells, 10 miles could not be registered with the same power. But if, between C and D, a derived circuit, or resistance coil, B, is inserted, whose resistance is to that of the galvanometer coil, as 1 to 10, nine-tenths of the discharge current will traverse the derived circuit B, and one-tenth the galvanometer. Thus, the deflection of the needle will be the same for 10 miles as for 1 mile. By varying the distance of the derived circuit by a set of resistance coils and rheostat, as in Fig. 8, and altering the power and unit of deflection, as may be necessary, it is possible to measure the discharge of any length of cable, for one mile and upwards. This is a valuable instrument for measuring the discharge of wires up to lengths of two hundred miles, or three hundred miles, but beyond that distance, the time of the discharge and the absorption of the charge would materially interfere with any measurement upon the needle. The thin line produced on a Bain's instrument, by the action of prussiate of potash on a steel wire, is a valuable test for the discharge of longer lengths of cable.

It will thus be seen that, by comparing the resistance with the discharge, it is easy to calculate the position of a fault, however distant from the testing place; the one is a check upon the other. But the experiments are liable to many errors, which, if not duly allowed for, produce serious mistakes. The most important relates to the resistance of the end, or fault. When the wire is completely severed, which is almost always the cause of the interruption to the working of submarine cables in shallow waters, the resistance of the end can easily be determined, as it depends entirely upon the surface of copper exposed in the water. By a series of careful experiments, detailed in the following Table, the Author is able to give the exact value of the resistance of the end, to any break in the cable under his charge.

TABLE II. RESISTANCE OF ENDS.—CHANNEL ISLANDS CABLE.

Length of Copper exposed, in inches.	Deflection of Needle from Water Battery.	Resistance, in Miles.		Difference.
		Positive Current.	Negative Current.	
4½	20°	1	1½	½
3½	15	1	1¾	¾
2½	10	1	2	1
1½	20	1	2½	1½
½	5	1⅓	3⅓	2
¼	22	1½	3¾	2¼
⅛	22	2½	4	1¼
Flush.	18	3⅓	5½	2⅙

'Gas currents' observed immediately after breaking contact.
Positive primary gave a negative gas current of 15°.
Negative „ positive „ 20°.

No great variation. Duration, about one minute; declining rapidly in the first and second, then gradually. Power, forty-eight cells.

A similar tabular statement could easily be obtained for any cable.

When the resistance of the end of a cable is small, and the break is not very distant, it is impossible to place any reliance upon the discharge of the wire, to verify its resistance, because a very peculiar effect is produced. When a negative current is sent through the wire, it is well known, that its end is covered with hydrogen gas, by the electrolytic action of the current upon the water, and, by the same means, the end becomes coated with oxygen, when a positive current is used. Now these two gases, acting upon the exposed end, themselves generate weak currents, which are often mistaken for discharge. The Author designates them 'gas currents,' to distinguish them from the 'water current,' which is always generated by the voltaic arrangement of the exposed copper end, the sea water, and the outside iron covering. A positive primary current generates a negative gas current, and *vice versâ*. The duration of this current is but momentary, and it varies little with the surface of the copper exposed. Its electro-motive force is slight, but it renders perfectly nugatory any attempt to verify the resistance tests of short lengths, by those of induction. These gas currents are identical with 'currents of polarisation.' When the copper wire is in contact with the outer iron wire, a case of very rare occurrence, these currents are not observed, nor does the end give any resistance, a fact which is also corroborated by the resistance given to the positive and negative currents being equal. This was the case in No. 8, Table I.; (page 33).

The occurrence of partial faults is another cause of error, and great care is requisite to maintain a thorough knowledge of the condition of the wire, and the position of these partial faults. A partial fault is a leakage, or imperfection, in the insulating medium, which does not interrupt the working of the wire, but which reduces the efficiency of the working currents. In practice, daily observations should be made, at each end of a submarine cable, to detect and determine the position of these faults, as the errors they produce are very serious. In testing from Weymouth, the Author calculated the fault No. 10, Table I., to be at 15 miles from Alderney. This arose from the existence of a partial fault near Weymouth; on testing from the other end, he found the result shown on the Table.

If A B (Fig. 10) represents the wire to be tested, and A C a fault near at hand, then the resistance of the two together will be, by Ohm's law, calling the one x and the other y:—

$$\frac{x\,y}{x+y}.$$

Now if $$y = \mathrm{B}$$

and $$\frac{x\,y}{x+y} = \mathrm{A}$$

then $$x = \frac{\mathrm{A\,B}}{\mathrm{A-B}}.$$

From this, it is evident, that the less the resistance y is made, the greater it will make the difference between A and x, and consequently, the greater the error produced in the test.

It can be similarly shown, that the further the fault is from A, and the greater its resistance, the less will be the error introduced. Hence, before the correct resistance of a wire can be definitely proved, the value of y must always be known. To show, practically, the serious error a partial fault may produce :—

Suppose $y = 100$,—by no means a very serious fault,—

and $$\frac{x\,y}{x+y} = 48$$

then $$x = 92\tfrac{4}{13}:$$

reducing the distance of the fault by nearly one-half.

There are several methods of testing for partial faults. The following are those usually adopted :—

First, When the two ends are at hand ;—by inserting resistance at A, (Fig. 11,) until the differential galvanometer marks zero ; and calling R the resistance of the cable, when perfect ;
„ x „ of the longer length ;
„ y „ of the shorter length ;
„ r „ of the coils ;

then $$x + y = \mathrm{R}$$

and $$x = y + r$$

$$\therefore 2y = \mathrm{R} - r$$

$$y = \frac{\mathrm{R} - r}{2}.$$

Secondly, When only one end is obtainable :—

Let $x + y = \mathrm{R}$, resistance of the cable, when perfect ;
$x + z = \mathrm{A}$, the resistance, when the end is disconnected ;

then $x + \dfrac{y\,z}{y+z} = \mathrm{B}$, the resistance, when the end is to earth ;

from which x, y, and z can easily be resolved ; x and y being the distances of the fault from the ends, and z, the resistance of the fault. This method requires great care, and is liable to serious errors through the variability of the resistance of the fault. The test should be verified by repetition at the other end, but the Author prefers to obtain simultaneous tests, at both ends, by two manipulators, who possess instruments precisely similar in every respect, by which method great accuracy is obtained, and the variation of the resistance of the fault is of little, or no, consequence.

The methods of testing by resistance and induction, which have now been detailed, will enable the Engineer to possess a thorough knowledge of the condition of the wire under his charge, and to detect, at once, the existence and position of any fault, however distant, which may occur to interfere with the proper working of the cable.

Faults are of various kinds, and result from various causes. There are faults arising to the insulating material, from adulteration in its composition, and imperfections in its manufacture. There are mechanical injuries sustained by the gutta percha in its transport from the manufactory to the machine, or in the process of making it into a submarine cable. The cable is liable to injury, in every stage of its existence; and when submerged, it is in the greatest danger. In shallow waters, rocks destroy it, and ships damage it with their anchors. Atmospheric electricity plays an important part in its existence, in deep as well as in shallow waters; one flash of lightning, entering the wire, would speedily destroy its utility. The immoderate use of battery power would irretrievably destroy a damaged wire. But there is no imperfection which cannot be detected, and no accident which cannot be provided against. If the cable is thoroughly examined and tested, before it enters the machine; if it is completely supervised, and tested under water, before being coiled in the ship; if it is payed out, with due regard to the course taken, and the nature of the bottom; if in shallow waters it is made so strong, that no ship can injure it, and it is laid along such a route, that no rocks can damage it; if it is properly protected against lightning and other natural causes; and if it is constructed, and worked, upon true principles; then submarine telegraphy may hope to flourish. But when all experience is ignored, and the true principles of the science are neglected; when a red line is drawn across a chart, and a cable is laid along that route, without any reference to the currents, and the bottom; when cables, which, in their design, are scarcely fit for unfrequented rivers, are laid in rough channels; and when no regard whatever is paid to their durability and maintenance; then no surprise need be felt, that opinions should be expressed unfavourable to the permanence and efficiency of submarine telegraphy.[1]

The Paper is illustrated by a series of diagrams, from which Plate 2, (Figs. 1 to 11,) has been compiled.

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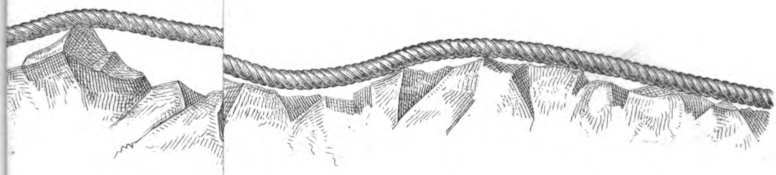
[1] It is gratifying to the Author to find, that the conclusions he had arrived at, and the opinions he had expressed in this Paper, were corroborated and confirmed by the Joint Committee in their Report to the Government, issued in 1861. Several accidents of a similar nature to those described, have occurred to the Channel Islands cable, and the undertaking is now being abandoned.—AUTHOR. February, 1862.

[Mr. HAWKSHAW,

Fig: 4.



CABLE LYING TIGHT ON ROCKY BOTTOM.

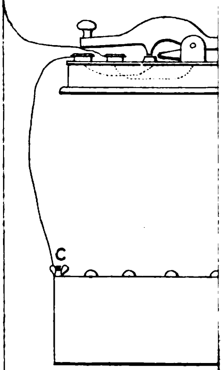
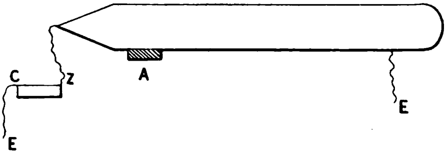


Fig: 11.



KELL, BROS LITHRS CASTLE ST HOLBORN.

Mr. **Hawkshaw**, V.P., observed, that during the last two generations, there had been three great movements in the engineering world; one, when Watt invented the steam engine, which supplied power; another, when railways were introduced, which supplied locomotion, and the third was the invention of the electric telegraph, which, as an agent for transmitting thought, he considered to be as important as either of the others. Those who had paid attention to the subject, knew the great progress which had already been made in the science of electricity; yet he believed it to be still in its infancy. The Paper before the Institution was one of the most important which had been presented, and it afforded a convincing proof of the rapid advances now taking place in one of the most valuable fields of scientific research.

Mr. **W. H. Preece** remarked, that, in condensing the Paper within reasonable limits, he had, necessarily, been obliged to omit many particulars deserving of notice; he had, however, carried out as well as he was able, his intention of forming a framework, upon which a discussion might be raised. He had scarcely alluded to the effect of temperature upon wires, which was a frequent cause of serious error, nor to the defects of stranded wire. He felt, that it would have been desirable to have given greater extension to his remarks upon testing under water, upon working damaged wires with single currents, and upon the comparative advantages of screw and of paddle-wheel steamers in repairing cables; and he should, more particularly, have referred to the improvements in testing, of Messrs. Siemens, Halske, & Co., of Berlin, whose instruments, exhibited before the British Association, accomplished, although in a different manner, the objects he had pointed out. On reference to No. 4 of the Table of Fractures, (page 33,) it appeared, that the actual fault was only $\frac{3}{4}$ths of a mile from Jersey; while the testing gave $1\frac{1}{2}$ mile, an apparent error of 100 per cent. But the error was not a per-centage error, it was simply an error due to the resistance of the end; and had the test been made at a distance of 100 miles, the difference of $\frac{3}{4}$ths of a mile would have still been the same.

The chief points for discussion were the importance of thoroughly surveying the route before laying the cable; the choice of a proper insulating medium; and the necessity of applying some exterior protecting coating to all cables, not only in shallow water, but also in deep seas. The want of coating to retain unimpaired the strength of the cable, was exemplified in the case of some of the recent failures in deep-sea cables, and particularly, in that of the Atlantic cable. Had the latter been protected against the action of the sea water upon the outer wires, its repair would have been easy, and the transmission of messages across the Atlantic, would now be in full operation. The Report of Mr.

Varley showed, that the wires had become so decayed, as to be incapable of repair, whilst those parts which had been coated with hemp, were as good as when the cable was first laid. Again, in the case of the Red Sea cable, he had heard, that those who undertook the repairs, found the cable, when brought to the surface, similarly decayed. Some cables, however, had been made, which partially carried out the ideas he advocated; the one most recently laid was the Toulon and Algiers cable, which had a covering of hemp. The Red Sea cable was the best specimen that had been brought forward, at the time it was laid, and if it was combined with the principle of the Algiers cable, the former acting as a cone for the outer wires of the latter, he thought that the proper form for a deep-sea cable would be attained; the former giving strength, and the latter, durability. In cables similar to the Algiers cable, a 'kink' would occasionally occur, and cause serious damage, but he believed that was a defect which would easily be overcome, by the cable he suggested.

The important question of insulating media had occupied the attention of the Government; and the Commission which had been appointed had, he understood, collected some interesting facts relating to it. That Commission, however, had not yet published its Report. He quite agreed with the remark, that submarine telegraphy was still in its infancy, but the knowledge of the correct form and construction of cables could never be ascertained, except by the accumulated experience of all those who were engaged upon the subject. His own experience had been freely placed before the Institution, and if others would, in like manner, contribute their quota of information, Engineers would, ere long, arrive at the true form of submarine cable, both for efficiency and durability.

Mr. CROMWELL F. VARLEY called attention to what he considered were errors in the calculations of the reduced resistances, in the instruments described in the Paper.

Mr. W. H. PREECE observed, that he had pointed out in the Paper, the means of compensating the irregularity alluded to. He had, generally, in making these instruments, taken the amounts of resistance experimentally, which gave the result required.

Mr. VARLEY continued. With regard to the mode of measuring and using a derived circuit, the first idea was suggested to him by Professor Thomson; and he described an instrument for effecting a similar object to that proposed by Mr. Preece, but based upon a different principle. It did not appear to him, that the induction formula correctly expressed the discharge from different cables, because it did not show, that the ratios between the diameters of the interior conductor and the outer covering, remained constant, and because it omitted the specific inductive capacity of the material employed.

Some remarks had been made as to the insulating powers of different materials, on which he would offer a few observations; and as gutta percha had, hitherto, been exclusively used, he would speak of that material first. The manufacture and preparation of gutta percha had, recently, been much improved by the Gutta Percha Company. They had produced specimens more compact to the eye, with as low an inductive capacity as india rubber, whilst the insulating power had, he believed, been increased forty times. The gutta percha, as now prepared, possessed insulating power enough for all practical purposes, in working cables; but in testing, the higher insulating power would be of great service. If this new preparation of gutta percha could be sold at a reasonable price, a material would be obtained, which would test more perfectly than common gutta percha, and it would also have the advantage of allowing a higher rate of transmission; for whilst with the ordinary gutta percha, only 7·45 words per minute could be sent, with this new substance, 12 words per minute might be transmitted. Pure india rubber seemed to give the greatest resistance to induction, of any substance that had been examined. The next material, which was on a par with this special gutta percha, had been introduced by Mr. Wray, and was a composition of india rubber, shellac, and ground glass. Some specimens charged over-night, were not found to have sustained any appreciable loss, when tested the following morning; and one specimen, a yard in length, retained its charge with a very trifling loss, for a fortnight. Vulcanised india rubber, as applied by Mr. Daft, (Assoc. Inst. C.E.,) was also a promising substance. Although considerable improvements had been made in insulating materials, none had yet been adopted, to any great extent, except india rubber and gutta percha. It was very desirable that telegraph companies should institute a series of experiments on a large scale, to test the merits of different insulating materials.

As an illustration of the importance of ascertaining, with some degree of accuracy, the nature of the bottom on which the cable was to rest, Mr. Varley stated, that he and Captain Kelk had found the Atlantic cable lying upon a reef of rocks across Trinity Bay, Newfoundland, which was the continuation of a range striking out from the shore, at about 15 fathoms below the surface of the water, in a position where the charts indicated a depth of 50 fathoms, and upon these rocks, the cable had suffered severely. He had seen parts of the iron wire of this cable, where it was covered with hemp saturated with Stockholm tar, which had retained its brightness, after having been immersed in the sea for a long time, a result attributable, he believed, to the preservative properties of the tar, rather than to those of the hemp. The portions not so protected, were found to be corroded to such an extent, that it was not possible to raise the cable, without constantly breaking the thin wires, of which the outer covering was composed. There were evidences of metallic copper on the outside of the iron wire, and as the gutta percha was quite sound, it could not have resulted from the decomposition of the copper wire of the cable. He imagined, that it must have arisen from the cable resting upon some copper ore, at the bottom of the sea. In the first cable which was laid from Hurst Castle to the Isle of Wight, some of the wires were found to be eaten through, whilst others were sound. On that coast, there were large quantities of stone, which was used for the manufacture of cement, and which was known to contain red oxide of iron. This ironstone, when tested against copper, was found to be highly negative, and where iron rested upon it, the iron was certain to be corroded. The only method of preventing that action, and of preserving the wires, was to insulate them by a covering of yarn and of some pitchy compound. He thought, that zinc only afforded a partial protection, owing to its impurity, but that tinning would be more effective, and not more expensive than galvanising. As regarded the Atlantic cable, an observation had been made, that if it had been covered with a protecting coating, it might still have been in good working order. He entertained a different opinion; because, as shown by the tests to which it was subjected by Professor Thomson, it was, undoubtedly, defective, before it was submerged. It was never tested before being laid, and that had been the case with almost all the other cables that had failed. He believed the failure of the Atlantic cable was not due to any imperfection in the gutta percha, but to gross carelessness and want of knowledge.

Mr. Bidder,—President,—said, that an approach was gradually being made to a correct appreciation of electrical phenomena and the proper condition of telegraph cables; and within a short period, the science of the transmission of electric currents, through wires insulated in various substances, would, probably, be brought within the range of formulæ, as accurate as those which determined the flow of water, through pipes of various diameters. But in order to utilise that knowledge, it was also necessary to ascertain the proper method of laying down electric cables, both in deep and in shallow water, and of maintaining them in a state of efficiency, after their submersion. The progress in this respect, had been, hitherto, extremely unsatisfactory; there had been a disastrous failure in the Atlantic cable, and if possible, a still more signal failure in the Red Sea telegraph. He hoped, therefore, that the discussion would not be confined to the theory of electricity, but that it would also be directed to the practical point of rendering the knowledge and information available, as a great commercial and national object. He should take an opportunity, at the close of the discussion, of making some remarks upon the subject, and he should not shrink, through any fear of giving offence, from frankly expressing his own opinions upon a question of such vast national importance. The Commission, appointed by the Government, was now sitting, and had collected a considerable amount of information; but all the evidence was of a purely voluntary character, and could not, therefore, be subjected to a searching cross-examination. For that reason, he thought that a discussion at the Institution, fairly analysing all that had been hitherto done, and bringing forward accurate facts, would be of assistance to the Commission, and that it would also have a great effect in relieving the profession from the cloud that was, at present, hanging over that particular department of engineering science.

Mr. C. W. Siemens felt more than usual difficulty in approaching the subject, because the Paper, although dealing only with the phenomena which presented themselves in the treatment and management of some short lines of telegraph cables, opened for discussion a branch of science which embraced many others, from chemistry to naval architecture.

He had engaged, on the part of the Contractors, to superintend the electrical condition of the Channel Islands cable, during its submersion, and also to arrange the instruments of the line. At the time the cable was laid, nothing could be more satisfactory than the results it afforded. The electrical condition was, considering the state of perfection then arrived at, very satisfactory; the instruments acted with the greatest facility, and with very low battery power; and he took this opportunity of stating, that he considered it an essential point, to save a cable as much as possible from the strain of great battery power. The Paper dealt, more particularly, with the mechanical accidents that occurred to the cable, upon which, he would, in passing, make a few remarks. The route, as was justly stated, was not well chosen; it would have been better, no doubt, had it passed direct from the Isle of Wight to Guernsey; but he was under the impression, that the choice of the route was not left to the Contractors, but that it was, as had generally been the case, determined by the Company, in concert with the Government. He also agreed with the Author, that the shore ends had, generally, been made too light, and that the specimens he exhibited presented far greater power of resistance to wear and tear. But Mr. Siemens had adopted the plan, when laying electric wires across rivers, or bays, of inclosing them in a succession of tubes, connected together by universal joints. This plan was more advantageous than using a strong cable, for each tube took a firm position upon broken ground, allowing the cable inside to make its own permanent serpentine curve; whereas a strong cable would, owing to its elasticity, always be moving between its supports, and be thus exposed to continual abrasion.

Passing to the larger work of the Red Sea cable, he would, first, explain the position in which he had stood with regard to that undertaking, or rather the position of the firm of Messrs. Siemens, Halske, and Co., of which he was a partner. They were employed to superintend the electrical condition of the cable during submersion. Unfortunately, they had not had an opportunity of examining the cable regularly, until it was on board ship; and it was one of the most prolific causes of failure, that cables were not thoroughly tested under water, before they were deposited in the ocean. In laying the Red Sea cable, faults occasionally occurred, which, by the system of testing adopted, were instantly detected and rectified; but none of these would have happened, if the cable had been previously immerged. When the operation was completed, it proved, like most lines when just laid, very successful. The telegraph was worked from Alexandria to Aden, a distance of 1,200 miles, with double relay stations at Kosseir, and Suakin, at the rate of ten words per minute; and the general condition of the line was such as must be pronounced to have satisfied the terms of the contracts. There were, no doubt, a few embryo faults, which, by their system of testing every five minutes during submersion, they were enabled to trace, and to map by means of diagrams, representing the copper and gutta-percha resistances. The times of observation were not left to the discretion of those on land, and on board the ship, from which the cable was payed out, but they were prescribed by a peculiar clockwork arrangement, which reduced the work of the observer to a simple registration, and obviated much uncertainty and delay in these operations. The line was in a satisfactory electrical condition when laid, and he believed it might have been worked successfully, for a considerable space of time, if a permanent system of daily tests and of timely repairs had been, at once, established. The Author had mentioned some of the difficulties with which cables had to contend, and the injuries to which they were exposed, but probably, he had not had an opportunity of watching the effects of tropical heat, or of metallic veins at the bottom of the sea, which also tended to destroy them. He could refer to several cables, which had remained perfectly sound for a certain distance, but had been, in certain places, so completely corroded, that in attempting to repair them, they, literally, fell to pieces. Such had been the case, as had been already mentioned, with the Atlantic cable. It was too much the fashion to regard a cable, when once laid, as of indefinite durability, and, in most cases, no sufficient means were adopted to test it at regular intervals. No means, for instance, were provided for effecting repairs in the Red Sea cable, as the necessity might arise, and under those circumstances, it was surprising, that it should have lasted for nine months before the first fault occurred, it having given way only the day before the extension was completed to India. Upon the return of the expedition engaged in laying the cable, it was the general opinion, that energetic measures should be adopted for its maintenance. The neglect of this might, in a great measure, be attributed to the diverse interests of the several parties concerned. There was the Government, who had given an absolute guarantee to the Company, which had the management of the line, without being sufficiently interested in maintaining it in good working condition; there was the Contractor, who had fulfilled his engagement, when once the line was successfully laid; there was the Pioneer, who had laid down the direction it should take, but who had not had sufficient opportunity of testing the nature of the bottom; there was the Engineer, who superintended the making and submerging of the cable on behalf of the Company; and finally, there was the Electrician, who had, probably, the most anxious and trying work of all, but the importance of whose office had not, he thought, been sufficiently considered, in making the general arrangements. The necessity of adopting a better system, was, however, beginning to be acknowledged; in proof of which, he would instance the Government cable, about to be laid between Rangoon and Singapore, where an opportunity had been afforded, for the first time, of carrying out a complete system of testing, before the cable was shipped.

The method of testing employed by Messrs. Siemens, differed essentially from those hitherto adopted. He would not, at present, enter upon the mathematical part of this subject, which was very intricate, but would confine himself to giving an outline, which would sufficiently show the relative advantages of the system, referring those who might feel more interested in the subject, to a Paper by his Brother and himself, read, in 1860, before the British Association at Oxford.[1] The old system was to test the insulation by the galvanometer, and to judge the condition of the line by the angle of deflection, and the battery power employed. This was unsatisfactory, for the angle of deflection of an instrument was never the same for two consecutive days, nor could an instrument be constructed with a constant amount of deflection for the same current; there was, therefore, no means of comparing results. If a mile of cable was measured by one instrument, and several miles by another, or by the same instrument the next day, no useful comparison could be made. But Messrs. Siemens adopted the method of expressing the conductivity of the insulating coating, as well as of the conductor, by certain units of resistance. The unit adopted by the Author, and which might suffice for the particular case mentioned in the Paper, was the mile of No. 16 copper wire. It resulted, however, from the investigations of Dr. Matthiessen, that the copper of commerce varied in its conductivity, between the limits of 100 and 7; in speaking, therefore, of the resistance of a mile of copper wire, no distinct estimate of its value could be formed. The unit developed by his Brother, and which had since been adopted by them in all their operations, was the resistance of a column of pure mercury of one mètre in length, and one millimètre in sectional area; this unit possessed, over others, the advantages of being invariable, and of being easily reproduced.

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[1] *Vide* "Outline of the Principles and Practice involved in dealing with the Electrical Conditions of Submarine Electric Telegraphs," by M. Werner and C. W. Siemens, in the "Report of the Joint Committee appointed to Inquire into the Construction of Submarine Telegraph Cables." Folio. London, 1861. Page 455.

Coils of resistance were next formed of German silver wire, representing, respectively, units, tens, hundreds, thousands, and tens of thousands of units of resistance. By introducing these variable resistances into the three sides of a Wheatstone's bridge, or electric balance, the resistance of the fourth side, which was the gutta-percha, or copper conductor of the cable under examination, could be ascertained with the utmost certainty, the limit of error not exceeding, practically, one in one thousand. It was desirable, sometimes, to determine fractions of units, in measuring copper conductors; and at others, millions of units, in measuring the gutta-percha resistance of a short piece of cable, to accomplish which the apparatus could be modified in different ways. Another feature of this method of testing consisted in the close observance of the time during which the electric current was allowed to act, before the observation was taken. This was of the utmost importance, in order to obtain results that could be relied upon, for the conductivity of gutta percha was changed, even for days, by the application of electric currents. Their method of ascertaining the inductive capacity of cables was also peculiar, being based upon their discovery, that inductive tension, in passing from the conductor through the insulating covering, followed the simple law of Ohm, regarding electric condition, and admitted, therefore, of being subjected to the same precise methods of measurement. Although this system of testing cables had not been long in use, resistance coils had been employed by them, since the year 1849, for determining the position of faults in subterranean lines.

In the case of the Rangoon cable, each mile of core was tested at the works, after submersion during twenty-four hours in water, at a temperature of 75°. Comparative testing would be useless, unless made at the same temperature, because the conductivity of gutta percha increased in a very unequal ratio, with the increase of temperature. After submersion, the cable was placed in Reid's pressure tank, in order to discover the existence of any cavities in the covering, but the pressure that could be applied was insufficient to force the water into the cavities of the lower coatings. The results of the electrical tests were then noted in tables, reduced to units of resistance per nautical mile. Having thus obtained a complete record of the copper and gutta-percha resistances of each mile of cable, it was sent to the wire works to be covered with hemp and iron. By this complete record, or table, it would be possible to detect the slightest fault, where lengths of the core, equal to, say one hundred miles, had been joined together; the copper resistance should not, in that case, exceed the sum of all the resistances contained in the table, due allowance being made for change of temperature, whilst the resistance of the gutta percha should not be less than the sum of the resistances, divided by 100. If it varied, it was a sure indication, that there was some defect which, after the cable was laid, would, probably, develop itself into a fault. But the value of these tests extended much further; if either during the laying of the cable, or afterwards, any slight decrease of insulation occurred, it would, at once, show the existence of a slight fault, although the line, if measured by others unacquainted with the previous tests, might appear perfect. The position of that fault should be immediately determined, and be carefully watched from day to day. In fact, complete records of the condition of the cable ought to be telegraphed each day, or each second day, to the chief superintendent of the line, in order that he might be able to direct timely operations of repairs. So long as there was a single fault in the line, they could, by their methods of testing, find out its position with the greatest certainty.

It had been, originally, intended that the Rangoon cable should be immersed in water during its entire progress. After having been tested at the Gutta-Percha Works, it was to have been placed at the Contractor's works in tanks, leaving them only for the short space of time necessary for passing the cable through the machine. From these tanks it was eventually to have been coiled into others on board the ships, in order that it might be payed out from water, into the sea. But the tanks of the Contractor were unable to support the great pressure of water, and thus the cable became exposed to atmospheric influences. It was soon observed, that there was a loss of insulation, indicating an increase of temperature, which, subsequently, became so great, that mist was seen to arise from one portion of the cable, and it became necessary to pour water over it. Thereupon, the Government requested Professor Miller to investigate the subject chemically, and they called upon Mr. Siemens to make a report on the electro-thermal phenomena.

It was requisite, for this purpose, to test the temperature of every part of the coil, for which Mr. Siemens devised a peculiar thermometer, constructed upon the principle of the resistance of copper wire to the electric current, varying, in a fixed ratio, with the changes of temperature. It consisted of a rod, or tube of metal, round which were wound several layers of fine wire, covered with silk; and the whole was hermetically sealed with india rubber, and gutta percha, to prevent the access of the water. The two ends of the wire were then brought in contact with the instrument for measuring resistances. Supposing the coil to have been adjusted to represent, at zero, 100 units of resistance, then for every 1° Fahrenheit, the resistance would increase by 0·4 of a unit. The advantages of this thermometer were, that while it could be placed at almost inaccessible points, it could be read, at all times, with great accuracy. In coiling the cable on board, he inserted several of these thermometers, at different layers of the coil. The coil remained nearly a week on board, without his being able to test it; at the end of that time, it was at once apparent, that there had been a spontaneous generation of heat. On the 10th of November, 1859, the tests of the cable had given 553 millions of units per nautical mile, at the temperature of 49° Fahrenheit. On the 21st of the same month, when the cable was first tested on board, the gutta-percha resistance per nautical mile, had diminished to 199 millions, showing a considerable increase of heat, unless, indeed, the decrease was due to a fault. On the 1st of December, it was only 61 millions, showing a still further rise of temperature. At the Gutta-Percha Works the standard resistance per nautical mile, was 100 millions of units, at the temperature of 75° Fahrenheit. The different resistance thermometers inserted in the cable gave the following temperatures: 84°, 75°, and 62°; thus proving that the heat was unequally developing itself throughout the mass, the highest temperature being about 3 feet below the upper surface of the coil. On the 2nd of December, the insulation, or gutta-percha resistance, had decreased to 54 millions of units, and the temperature had increased about 3° Fahrenheit in every part. Water was then applied to the cable, and after some hours, the temperature was sensibly diminished. The cable had, till then, given no external signs of heat; the temperature of the hold itself was not greater than 60°, nor would a mercury thermometer, placed in any part of the hold, indicate a higher temperature; yet, when large quantities of water at 42° Fahrenheit, were poured on, it issued from the bottom of the hold at 72°, corroborating the results of the electrical observations. This occurrence proved, that it had been most injudicious not to have carried out the original plan, of having the cable placed in water-tight tanks on board the ships. It also led to the supposition, that the destruction of several previous cables, more particularly the Atlantic cable, which had been coiled wet on board, might, very probably, have been owing to the same cause. If the Rangoon cable, while in its heated condition, had been tested on board the 'Queen Victoria,' with the most accurate galvanometer, it would have been pronounced more perfect than any cable hitherto sent out, because the Red Sea cable gave, at ordinary temperatures, only 22 millions of units, and the Atlantic cable, when reduced to the same sectional area, only 7, or 8 millions of units; whereas the Rangoon cable did not fall below 61 millions. Yet if the heating had been allowed to continue only a few days longer, it was absolutely certain, that the gutta percha would have been softened, and the copper conductor would have sunk in the insulating medium.

A great desire was generally manifested, for some improvement upon the present construction of cables: and he believed there was great room for amelioration. An iron cable, without an external covering to protect it against the action of the water, should never be adopted. So far from the iron being an element of strength, it became an element of absolute weakness, when the cable required to be raised for repairs. It had frequently been observed, that the iron was oxidised, and in certain parts, rapidly destroyed; and if the ground was uneven, the cable would then even break by its own weight, between the points of support. But the outer covering should not be of hemp, for there had been cases of hemp-covered cables having been completely destroyed by marine animals. As to the cause of the generation of heat in the Rangoon cable, his own impression had been, that it was due to the fermentation of the hemp covering; he was bound, however, to add, that, in Professor Miller's opinion, it arose simply from the rusting of the iron. His own view was founded upon his observation, that the resistance thermometers between the coils in contact with the iron, exhibited a less temperature than would follow from the resistance of the copper of the cable itself; showing that the core of the cable was 5° hotter than the spaces between the iron covering. It might be, that both causes had been active in producing the rapid increase of heat, which had been observed.

The most important part, perhaps, of the cable was the insulating medium, for which many new substances had been proposed, each possessing some degree of merit. The great disadvantages attending the use of gutta percha were, that it was readily softened by heat, that it was affected chemically by every current that passed into it, and that it frequently contained cavities. The passage of electricity through gutta percha was due, not to its conductivity, but to a slight decomposition of the water which it contained. The consequence was, that in places where the thickness of the covering was much reduced by any accidental cause, a fault would gradually be produced, by the electrolytic action of the currents employed. He was, therefore, a strong advocate of low battery power, so long as gutta percha was employed for the insulating medium; and his instructions to the electrical staff proceeding to Rangoon were, that not more than twenty-two Daniell's cells should ever be used. India rubber possessed a much higher power of resistance to electricity than gutta percha. Wray's mixture, composed of india rubber, shellac, and powdered flint, and other compounds of india rubber possessed valuable properties as insulating materials. He had made some attempts to combine them in a cable, but he should refrain from entering further into this question, for his present object was rather to inquire into the causes of failure of the cables hitherto laid, than to consider the comparative merits of new projects.

In answer to a question from the President, Mr. Siemens stated, that the Red Sea telegraph was worked between Aden and Suez, from the summer of 1859 till February 1860.

Admiral FITZROY, as a practical seaman, would offer some remarks, bearing upon professional points, which might be of assistance to the younger Members of the Institution, who had not had experience in similar technical matters. He would first, however, advert to and corroborate a remark of the Author of the Paper, as to the little dependence that could be placed on marine surveys made previously to the last few years, with regard to the configuration, the description, and the nature of the bed of the sea, beyond 6 fathoms, or 7 fathoms of vertical depth. This was not owing to negligence on the part of the surveyors of former years, but because submarine telegraphy being so new a subject, it was only recently, that accurate and minute surveys of the bottom of the sea, had been considered indispensably necessary. The Surveyor of the Channel Islands, between 1820 and 1830, was Captain Martin White, one of the best practical marine surveyors ever employed, whose accuracy in detailing all that was then required, was most exemplary; he proved all his work by true bearings and horizontal angles, either by the theodolite, or the sextant, and not by a fallacious compass. It was exceedingly difficult, when on board a vessel paying out a submarine wire, or even in an ordinary sounding survey, to compare the position of a moving body in a tideway, with an exact spot on the chart, unless methods as exact as those employed by the scientific surveyor who prepared the charts, were used by those engaged in this department of nautical engineering. The compass was always a fallible guide, on which little reliance ought to be placed. The only depths considered of primary consequence in the early surveys, were those under 7 fathoms, the depth at which a large line-of-battle ship might strike the bottom. In the harbour of Alderney, not many months ago, a frigate struck upon a rock, which was not laid down on any chart:[1] and even at the entrance of Milford Haven, a rock had lately been discovered in the fairway channel, upon which it was possible for a large ship to strike.

With regard to the manner in which submarine wires had been, hitherto, supposed to be protected, when at the bottom of the sea, he maintained, that iron should, on no occasion whatever, be employed as a covering, or armour. Such a defence should be composed of copper, or some metal, or other substance, that would not oxidise, and would be capable of receiving a gradual calcareous deposit, which would become a permanent protection against damage, or decay. However expensive in the first instance, it would be much more economical, than to use a covering which would not last more than a few years. He had been told by Mr. Park, formerly Master Attendant of Portsmouth Dockyard, that they were obliged to lift the chain moorings throughout the harbour, at least once in about four years, because in certain places, the cables became so corroded, that they could no longer be trusted. In some South American ports, there were copper veins cropping out at the bottom. In the Bay of St. Blas, 40° South latitude, between the Rivers Plata and Negro, a ship lay two months moored by chain cables, one of which was found to be so corroded in that short time from lying across copper ore, cropping out, and exposed as rocky patches, or ridges, that the cable was condemned, even in a merchant ship. Several instances of a similar nature to the galvanic action of copper and saline moisture on iron, had been mentioned, as having occurred near St. John's, on the other side of the Atlantic, where the copper appeared to have very seriously affected the iron sheathing of the cable, at the places in contact with it. That iron and copper with saline moisture in contiguity, were rapidly antagonistic, had long been known. Many years ago, when Mr. Peake, now Master Shipwright, was an assistant in Woolwich Dockyard, a vessel which had been fitted with Sir Humphry Davy's iron 'protectors,' came into dock to be examined. The object of placing these bars of iron on the bottom, was to keep the copper clean, and the plan perfectly succeeded in this respect, but the iron became decomposed in less than a year, and was reduced to a condition resembling plumbago. Mr. Peake put some of this decomposed iron, wrapped in brown paper, into his coat-pocket, for future examination, but soon afterwards, smoke was observed to issue from his pocket, and the iron was found to be quite hot. This fact tended to corroborate Dr. Miller's view of spontaneous combustion, consequent on the decomposition of iron under certain circumstances. Admiral Fitzroy thought, that a sufficiently pliable, durable, and protective, as well as insulating composition might be devised, partly vitreous, or siliceous, and partly calcareous, with a mixture of lead, or other metallic substance. In his opinion, the insulator should not be a vegetable substance, such as gutta percha, or india rubber, (which was the better of the two,) but it should be such a composition as he had already mentioned. That such a composition would be discovered and applied to this important purpose, could hardly be doubted, when every year attested the progress made in chemical science and in its practical application. He would not further encroach on the Electrician's province than to state, that the result of his own efforts in that direction was, that wires of the purest copper, and of the largest diameter, when durably insulated, were much superior to combinations of small wires, used on the erroneous notion, that electricity required superficies for its transit, rather than sectional area.

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[1] Mr. May, the Resident Engineer of the Harbour Works at Alderney, writes under date of August, 1860, that the position of the rock "is laid down on the chart published by the Admiralty, and is one of the shoals drawn on the contract plan for the works for the purpose of being blown up." This contract plan was signed 3rd February, 1860, and the vessel did not touch on the rock until August, of that year.—EDITOR.

He would now advert to some purely nautical points. In paying out a cable from the extreme end of the stern of a vessel, it would greatly moderate the suddenness and the degree of vertical motion in pitching, if one, or two rafts were placed astern of the ship, to break and divide the vertical action; this would allow the wire to run out smoothly, without being subject to sudden jerks. Yielding floats, or buoys, should also be used. It was well known to those who had been engaged in sounding voyages, that it was only at a comparatively short distance from the shore, that the bottom was rocky and irregular; consequently, it was only at such places, or 'on soundings,' as it was termed by sailors, that protection of any kind was required for the wire, in the deep ocean. As far as experience had shown, scarcely more than the insulating covering was generally required, in great depths.

Mr. Latimer Clark would confine his remarks to a statement of his own experience, which might be more useful than theoretical opinions. Submarine cables for shallow waters might be comprised under four classes. First, the hempen cable: secondly, the galvanised iron cable: thirdly, the unprotected iron cable: and fourthly, the iron cable with some protecting covering. With respect to the hempen cables, there were mechanical defects sufficient to condemn their use, as in the few attempts that had been made to lay them in shallow waters, they had soon been destroyed by the continual action of the tide and of the rocks. Galvanised iron cables, of which many hundred miles had been laid from the English coast, had proved, wherever they had been embedded in mud, or sand, to be very durable; so much so, that some specimens which had been under water during four, or five years, looked so bright and new, that it was scarcely possible to believe they had been submerged at all. He considered galvanised iron cables buried in mud, or sand, might last for fifty years, or sixty years, or perhaps more; but wherever they were exposed to the free action of the tide, corrosion was certain to occur. Judging from his experience, galvanised cables had, in all cases, a durability of at least three years beyond that of unprotected iron cables, but after that time, the zinc generally disappeared, and all cables whether originally galvanised, or not, were alike acted upon by the sea water. This corrosion was conjectured to result from the cable lying upon copper ore, or some other material which was electro-negative with respect to iron. Sulphuret of copper would cause a galvanic action, and the iron would soon be corroded. Cables were often quite perfect for a great length, and then suddenly, there was a spot where a piece had been, as it were, carved out of the cable by some local corrosion; in some places the iron had disappeared altogether, and nothing was left but the hemp and gutta percha. If there was copper in the sea water, it would be deposited on the iron in the metallic form, and galvanic action would immediately commence.

The first cable between Hurst Castle and the Isle of Wight, which was laid only five, or six years ago, became, in eighteen months, so deeply corroded at places, from the action of the copper, or of some other material, that it was broken by a ship's anchor. This was replaced by a smaller cable, which did not last a year, and subsequently, by a third of stronger construction, which was now being superseded by a fourth cable. Three cables, therefore, had been already destroyed, partly by ships' anchors, and partly by corrosion. Pure sea water, he believed, was not sufficient alone to produce this destructive action upon iron; it was, probably, occasioned by copper, sulphuret of copper, iodine, or ozone held in solution. A cable buried in mud, or sand, was, of course, continually exposed to the action of the water, but as the same portion of water always remained in contact with the cable, he apprehended, that it gave off at first its corrosive element to the iron, and became incapable of further mischief. This would account for the greater durability of cables, under such circumstances. In 1859, he had attempted to imitate this action in a cable from Whitehaven to the Isle of Man, which he coated with asphalte, or rather with a serving of jute saturated with common asphalte; this process was inexpensive, and he thought the cable would last for a long period of time.

The failures of the Atlantic and the Red Sea cables demanded serious consideration. That some mischance should occur to the Atlantic cable was not surprising, when the limited experience then obtained, of submarine telegraphy in deep water, was taken into account. The cable was elegant in form and construction, but every seaman knew, that it would very soon rust away. But in the case of the Red Sea cable, there was no excuse for using unprotected iron, scarcely thicker than bell wire, for the covering, as there had then been abundant evidence to prove, that after being only a few months in the sea, it would become so rusted, that should any repairs be necessary, it would not be possible to lift the cable to the surface. In a conversation with the Secretary of that Company, he had intimated to him, that the outer covering could scarcely be expected to last more than two years, an opinion which the Secretary did not dispute. However, he certainly had not expected, that it would have failed so quickly as it had done. He believed, that in some cases, failure arose from the formation of black sulphuret of iron, arising from the decomposition of animal matter in contact with the cable. Similarly, the cable about to be sent to Rangoon, would not be fit for use for more than three, or four years, under the most favourable circumstances; and if repairs were required, it would be found to be so much decayed, that it would be impossible to raise it. It was much to be regretted, that such a costly cable, electrically perfect, and designed for deep water, should have been laid with the certainty, that in a short time, it would have to be replaced. It was also to be regretted, that a cable designed to be laid from Falmouth to Gibraltar, should have had its destination changed to a much warmer climate, because the electrical conductivity of gutta percha was greatly increased, or its insulation was impaired by heat. For warm latitudes, a less fusible material than gutta percha was preferable for the insulator.

He believed he might claim some credit to himself, for the testing instrument described by the Author. The ultimate principle of the instrument was by no means new, but the adaptation of it was his own; the Author, however, had paid more attention to the subject than himself, and had produced a useful and valuable instrument.

With respect to the paying out of cables, he would allude to a circumstance that repeatedly came under his notice. The captains of the vessels so employed, often steered direct from one point to another, being merely desirous of making the quickest passage, without reference to the position in which the cable should be laid. A vessel sailing direct from east to west, and encountering several tides, would deposit the cable in a number of zigzags. Such, for example, was the case between Dunwich and Zandvoort, on the coast of Holland; more cable being used, than was fairly required for the distance. Captains were, generally, so well satisfied with their own practical knowledge, that they often regarded the suggestions of landsmen, as an ignorant interference. But it was important to draw their attention to this fact, for by such steering, they not only wasted the cable, but they rendered it difficult, afterwards, to ascertain its position when repairs were required.

Mr. Bidder,—President,—said, that the discussion had taken a wide, a general, and a very important bearing. At the present moment, telegraphic communication with India was entirely an open question; all attempts to maintain it effectually having, hitherto, failed. It had also been announced, during the discussion, that the cable designed to be laid down from Rangoon to Singapore had exhibited evidences of spontaneous heating, as to the cause of which, discrepant opinions were entertained by scientific men. Mr. Siemens, (M. Inst. C.E.,) to whose energy and research into this subject it was difficult to do justice, had given one theory upon the subject, whilst Dr. Miller had propounded another. It had been ascertained, however, that the core of that cable was at a much higher temperature than the external covering. When such new and unexpected phenomena were presenting themselves, it became a most serious question, whether the country ought to continue to make such large sacrifices, in attempting to establish telegraphic communication with the extreme points of the empire, in the present state of information and experience upon the subject of submarine telegraphy, of which the importance could scarcely be over-rated. Money should not be spared in establishing telegraphic communications, if they could be thoroughly depended upon; but when £500,000 had been uselessly spent in one case, and £800,000 in another, in laying down a cable which had never carried a single message, and when a large additional sum was expended in unavailing attempts to render these cables useful, the greatest disappointment was, no doubt, occasioned to the public, and indeed, to the whole world. He would suggest, therefore, that the discussion should be directed to the consideration of what was best to be done under existing circumstances; and whether it was advisable to send to a distant part of the empire, a cable in such a condition as that which had been alluded to. An undertaking of this kind should be regarded in the same light, as the initiation of a railway between the Land's End and the Metropolis. In his opinion, preliminary steps should be taken to establish telegraphic communication between London and Alexandria, or some point on the Asiatic coast, and at the same time to examine whether it could not be also effected onwards by land, and to what extent it was possible to subsidise the Arab Sheikhs, so as to insure communication with India by two routes; the land route would, no doubt, be more economical in first cost, and still more so, in maintenance. Another important question to be considered, was the manner in which these telegraphic communications could be best established; whether by subsidising an intermediate company, like the Red Sea Company; or whether the Government itself should enter into a direct contract with men of character and responsibility, and if so, what should be the proper conditions, which would render the interests of the Contractors, coincident with those of the Government.

It would, however, appear, that submarine telegraphs were not only liable to accidents from physical causes, but to others arising from moral causes. In a cable lately submerged by the Electric and International Telegraph Company, one wire out of four, was entirely lost, and £4,000 or £5,000 had been expended in attempting to rectify the fault. On examination, it was found, that a nail had been skilfully inserted into the cable connecting the external covering with the conducting wires in the core. The Directors of the Company had come to the determination of paying half the expenses of a prosecution; but he had suggested, that a reward of £1,000, would more effectually lead to the discovery of the perpetrator of such an infamous act, and, no doubt, legal proceedings could be adopted.[1]

Mr. Marshman said, the inference which would naturally be drawn from the observations of Mr. Latimer Clark was, that a public company had expended a large sum of money, intrusted to them by the Government, in the construction and laying down of a cable, which they themselves, through their Secretary, acknowledged would not last more than about two years. Such an impression must be very injurious to the character of any public body, and it was his present object to remove that imputation. In a letter addressed to him, by Mr. Peel, the Secretary of the Red Sea Company, he stated, that his observations must have been entirely misunderstood, on the occasion referred to, and that they were never intended to bear the interpretation which had been put upon them. He "certainly was, at that time, under the impression, that if a cable had been once successfully laid in deep water, it was a matter of secondary importance, whether the outer covering lasted, or not, but he should never have presumed to offer an opinion, as to the probable durability of any form of submarine cable." In addition to these remarks of the Secretary, he would observe, that the question of the proper form of submarine telegraph cable to be adopted for this line, was a subject of long and intense solicitude to the Directors of the Company; that, in accordance with the request of the Treasury, the Board sought the opinions of some of the most eminent scientific authorities in London, to whom a specimen of the proposed cable was submitted, and who generally concurred in the propriety of adopting it; and further, that on no occasion, did these gentlemen dissuade the Directors from using a cable covered with iron wire. The advice of the late Mr. Robert Stephenson was also desired by the Board; but he declined to give a written opinion, on the ground, that the question did not exactly lie within his sphere of practice. At a personal interview, however, not of a business, or professional character, Mr. Stephenson said, that a light cable simply covered with hemp, was, probably, the form which would, ultimately, be generally adopted, and that wire-covered cables would only, hereafter, be found in the British Museum as antique curiosities; but as sufficient experience had not been gained as to the durability of the hempen cable, he could not recommend its adoption either to the Board, or to the Government, for this telegraph line; that the wire cable which had been recommended to the Board, and which was submitted to his inspection, was as good as any manufactured, at the present early stage of submarine telegraphy. He believed, that Mr. Robert Stephenson had also expressed himself in similar terms to the ex-officio Director of the Company, Mr. Stephenson, of the Treasury. Fortified by this and other opinions, the Board no longer hesitated to adopt that form of cable, covered with wire, which had been laid down in the Red Sea.

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[1] *Vide* "Guildhall, February 20th and 21st, 1861. Before Chief Justice Erle and a special jury. Glass *v.* Boswall. Transcript of Messrs. Cocks' short-hand notes." 8vo. London: Waterlow and Sons.

Mr. Marshman, in reply to a question from the President, as to whether any messages had been transmitted through the whole length of the cable, said, that pending the action which had been brought by the Contractors against the Company, he must abstain from discussing that point.

Mr. F. C. Webb, before addressing himself to the subject of the Paper, would refer to the so-called 'unknown' rock, in Alderney Harbour. Whether that rock was shown in the surveys published by the Admiralty, he could not say; but he could state that, thirteen years ago, he surveyed that harbour himself, and the rock on which the frigate struck, was shown upon the chart, which he now exhibited, on a scale of 3 chains to the inch. The rock, he was informed, was perfectly well known to all who were acquainted with the harbour, and it was laid down upon some of the oldest charts. It might be argued, that such a rock ought not to exist in a large harbour, but it would be difficult to construct a harbour at Alderney, without some rocks in it; all that could be done, was to lay them down in the survey as accurately as possible.

With regard to submarine cables, he thought their maintenance had been greatly neglected, in most of the later and larger undertakings. The theory, that a submarine cable once laid successfully, would last indefinitely, had been, in general, acted upon too blindly. From his own experience, he considered, that this was a most dangerous principle upon which to act, in designing and constructing cables, and that, on the contrary, the more the Engineer regarded the probability of early failure, the greater would be the durability of the cable, because precautions would be taken to enable it to be easily repaired. On many lines, it had been the practice to select a small description of cable, and then a contract was entered into for making it, laying it down, and working it for a week, or a month. Upon the failure of the cable, difficulties were started about the depth at which it was laid, the size of the cable, the tightness with which it was payed out, and many other points which should have been considered beforehand. In selecting the route, the facility for repairing should be the first consideration, and although in deep water, a well-chosen cable might last for a long time, if perfectly laid, yet he thought, that deep water should be avoided where possible, even if a considerable détour had to be made. In a depth of 100 fathoms, a cable was, in most localities, beyond the reach of attrition, and it was as little likely to be injured, as when laid at a depth of 200 fathoms, or 300 fathoms; whilst it could be repaired almost as easily, as if it lay in water only 30 fathoms, or 40 fathoms deep. The nature of the bottom should also be considered, as where rough ground and rocks existed, the cable could not be easily grappled. To ascertain this correctly, the mere arming of the lead was not sufficient, as it only brought up a small portion of the surface material, which could give no information as to the presence of rocks, mud, or sand at the bottom; a mushroom anchor, which would bring up a bucketful of the surface material, and occasionally, deep-pronged grapnels, ought to be employed. The line should be divided into short sections, of about 100 miles in length; for although it might be possible to 'work' through 500 miles, or 1,000 miles, yet when one section was damaged, the consequences were more serious. Considerable portions of the Red Sea and Indian telegraph cables might have been laid, where they could easily have been grappled, and lifted for repairs; and in the line from Suez to India, there would not have been any difficulty in dividing it into sections of 50 miles each, throughout nearly the whole distance, except in crossing the Gulf of Oman, where a section of 120 miles would be required. He thought that, in the later lines, the strength of the cable had been much neglected. In the earlier cables, the aim was to make each stronger than its predecessor, but of late, the object appeared to be to construct them lighter, the question of maintenance being altogether disregarded. As long as a cable could be laid down, and a few messages transmitted, that was considered sufficient to meet the interests of all who had a voice in the management. In some cases it had happened, that the company owning the line, did not actually know where their cable was laid, having no plan of its course. In crossing the Atlantic, it was impossible to choose a line that could be maintained by yearly repairs; but between

England and India, a line could and should be chosen, on which a cable of suitable proportions and construction might be properly maintained, at a moderate yearly outlay.

MR. LATIMER CLARK would be extremely sorry, if he had been the means of conveying an impression, that the Red Sea and India Telegraph Company had manufactured and laid down a cable, which they believed, at the time, would not last. His object, in alluding to the conversation in question, was not to give the opinions of the Secretary, but to show what his own opinions were at that period. He was fully satisfied, that the Directors believed in the excellence of the cable they had selected, but so many instances had already occurred at that time, of the oxidation of the iron covering of cables, and their decay was so much a matter of notoriety, that provision ought to have been made to protect the iron from the destructive action of the sea water. With respect to the other cable alluded to, that must, eventually, be also destroyed, for it was not galvanised, and being covered with light wires, it was not calculated to last in salt water. He had forgotten to mention one point of interest connected with the cable between England and Holland. At one part, near the English shore, and at another on the opposite coast, seven of the small cables were found twisted together into one mass, which did not exhibit any symptoms of rust; whereas the single cables, lying under precisely the same conditions, rapidly oxidised. He might also state, that the thicker wire of the larger cables generally oxidized much less quickly, than the wires of the smaller and lighter cables.

Sir CHARLES BRIGHT was not able to follow the course of discussion suggested by the President, with respect to the Rangoon cable, and the way in which, under the present unfortunate circumstances, it could be best turned to account, because he was not in possession of any official information as to the details of the case, and he could speak only from rumour. He would, therefore, deal with the original subject of the Paper, the maintenance and durability of shoal-water cables. This question, in so far as it concerned the relative proportions of submarine cables for different depths of water, had already been brought under the notice of the Institution, in 1858, by the Paper of Messrs. Longridge, (M. Inst. C.E.,) and Brooks,[1] which was principally devoted to a mathematical consideration of the requirements and conditions of deep-sea cables, and recommended the lightest possible form of cable for such lines. After a long discussion upon the subject, he retained the same opinion he had held before, that although, as a matter of theory, the lightest possible form of cable might appear most desirable for deep water, yet in practice, unless a certain amount of weight was put into the cable, so as to cause it to reach the hollow before the paying-out ship was too far distant, and to accommodate itself to the irregularities of the bed on which it was laid, no deep sea-cable could be durable. A hemp-covered cable had been suggested, but even supposing the objection which he had mentioned to be disposed of, he did not yet see his way to the manufacture of a good cable of this class, which would get rid of the difficulty of the pressure of the water causing the fibres of the material to contract, and thereby, to influence the gutta-percha core, which would not be affected in the same manner. The cable which he had recommended to Government for the Falmouth and Gibraltar line, possessed many advantageous features. He did not, however, wish to be understood as expressing his approval of the Rangoon and Singapore cable, which had the core of the proposed Falmouth line, but which he did not consider well adapted to the depth and bottom of the route, over which it was to be laid.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xvii., p. 221.

The immediate question before the Meeting was the durability and maintenance of cables in shoal water. As was also the case in deep-sea lines, there were two schools, as it were, of Engineers, holding opposite opinions in regard to shoal-water cables, one advocating and adopting comparatively light cables, the other making them as heavy as possible. On considering the numerous calamities which had befallen the lines of the Channel Islands Company, as shown in Table I., (page 33,) which presented records of eleven fractures within a very short period of time, it required no lengthy argument from him to prove which was right, and that cables of that class could not be suitable for shoal water.

It might be useful to refer very briefly to the early history of submarine telegraphy. The first submarine cable of any length, was the Dover and Calais line, which was laid in 1851, by Mr. Crampton, (M. Inst. C.E.,) for the Submarine Telegraph Company. This was followed by the Dover and Ostend, and the Magnetic Company's lines to Ireland, and other strong cables, all of which contained several conducting wires covered with a thick serving of hemp, and protected by massive iron wires of large gauge. Those cables had been singularly fortunate. It was true, that some of them had been injured by ships' anchors, but such occurrences were rare, their great strength protecting them from harm from any but large vessels; but they had never suffered from some of the causes enumerated in Table I., such as 'abrasion,' or being 'washed away by the sea.' The new system of laying light cables in shoal water, from which the Channel Islands Company was suffering so grievously, was first adopted by the Electric Company in their lines from Orfordness to the Hague, where, instead of laying one strong and heavy iron cable, four comparatively light cables, each with one conductor only, were laid across the North Sea, on the principle, that the chances were against all the four being broken down at the same time. That system which had also been adopted between Dublin and Holyhead, had been, however, far from satisfactory, the annual cost for repairs having amounted, during several years, to from £10,000 to £12,000, and the Company had been, finally, compelled to lay a heavy cable from Dunwich to Zandvoort, in Holland, the working of which had been very successful. The same error which had proved so fatal to the Channel Islands line, had been pursued on the Red Sea line, where the cable was laid, to a great extent, in shoal water. With these exceptions, however, all the shoal-water lines which he then remembered, had been laid with strong cables, and there were many in existence in different parts of the world, which had only required the most trifling expenditure for repairs, since the date of their submersion. He had himself had very little experience in repairing submarine cables, for although he had several important cables for some years under his charge, they had cost nothing whatever for repairs up to that date. In two cases, they were necessarily laid on a rocky bottom, and were subject to the action of strong currents, but they were heavy cables of great strength, laid with sufficient slack to meet any irregularities in the bed of the sea. He might also instance the heavy cables laid in 1854, between Spezia and Corsica, and across the Straits of Bonifacio, passing over depths of between 700 fathoms and 800 fathoms of water, crossing several reefs, and being also laid in shoal water for some distance; yet these cables had worked well and continuously. The line laid by Messrs. Glass and Elliott for the Submarine Company, from St. Catherine's in Jersey, to Pirhou on the coast of Normandy, (Fig. 1,) although not very much larger in dimensions, than the Channel Islands Company's cable, had from some cause, or other, been more successful, for it had never given any trouble since it was laid; while during the same period, the other line had suffered no less than six of the interruptions recorded in the Paper. Whether this was owing to the manner in which the two lines were laid, he was unable to say, but he was on board during the laying of the Normandy line, and the operation was effected with great care. He did not, of course, mean it to be inferred, that any of the cables of which he had spoken, would have given satisfactory results, had they been improperly laid; but he thought there was sufficient reason for concluding, that the casualties which had occurred, could not be considered as inherent, of necessity, in shoal-water cables. It was evident, that the cables themselves were not suited to the work, and he thought, that a continual recurrence of the disastrous fractures, could be easily prevented by proper means.

The Paper had treated, principally, of the various arrangements devised for testing, from the shore, the position of faults in submarine cables, and he thought it would be interesting to those who, from want of experience in telegraphic experiments, were unable to follow the technicalities of the formula which had been given, to explain, in simple language, the principles involved in the first plan proposed for the purpose, by his Brother and himself, in 1852, shortly after the laying of the first cable. An electric current having the choice of two routes, would pass by that which was shortest, or which offered the least resistance, being divided proportionately, according to the conditions of the circuits. The power of artificially representing, by coils of fine wire, the resistance of a much greater length of wire of the larger section used for telegraphic purposes, was also well understood. A submarine, or underground conductor, which was fractured, or defective in its insulating covering, would be connected to the earth at the point of defect, by the sea in the one case, and by the humidity of the ground in the other. If now, a battery was connected by one pole to earth, and by the other to one side of a galvanometer, the other side of which was connected to the defective conductor, and also to another galvanometer, (or to the other coil of a differential galvanometer), the other side of which was connected to a coil, or series of coils, of fine wire, the end of which was connected to earth; then by adding coils of fine wire to the series, until the current divided itself equally through the two galvanometer coils, the length of the conductor between the testing place and the fault might be calculated, by allowing for the resistance offered by the fault itself to the full and perfect passage of the current, which was determined by a different process. The connection to earth was an important feature of the arrangement, and with this and some other modifications, Professor Wheatstone's ingenious instruments for determining the resistance of various bodies might be turned to similar account. In fact, all the processes which had been mentioned in the Paper and in the discussion, had been modifications of the system of using resistance coils in connection with the earth, with more, or less of Professor Wheatstone's appliances engrafted upon it. He was, therefore, somewhat at a loss to understand the many claims put forward for the first invention of various parts of the system, which had been an established fact before the claimants had much experience in telegraphy, and certainly, none in submarine telegraphs.

Sir Charles Bright, in reply to a question from the President, said, that for the Rangoon and Singapore line, he should have recommended a cable well protected from oxidation, and stronger than the one about to be laid down.

Mr. C. W. Siemens, in answer to a question from the President, replied, that the testing of the cable had been continued on board the Queen Victoria, with results confirming his previous statements. Unless the cable was effectually cooled by pumping cold water over it daily, the heat increased at the rate of about 3° Farenheit per day. Considering that the weight of cable on board that vessel amounted to more than 1,000 tons, it was evident, that the amount of heat generated daily was considerable, and that very effective measures would have to be adopted, if it was to reach its destination in safety.

Mr. FORDE said, that although the Chairman of the Red Sea Telegraph Company had stated reasons, for not discussing certain points connected with that enterprise, there were some facts relative to which no concealment need be observed. The line was divided into six sections, three of which were in the Red Sea. The first was from Suez to Cossire, 255 knots; the second was from Cossire to Suakin, 474 knots; and the third was from Suakin to Aden, 630 knots; in all, 1,359 knots of direct distance, between Suez and Aden. From Aden to the Kooria Mooria Islands the distance was 717 knots; from the Kooria Mooria Islands to Muscat, 486 knots; and from Muscat to Kurrachee, 481 knots: in all 1,684 knots between Aden and Kurrachee. The whole length of the Red Sea and Indian line was thus 3,043 knots. Messages had been transmitted between Aden and Suez, during a period of about nine months, and separate sections of this portion of the line had been worked during eighteen months. He was precluded from discussing the causes of the failure of the line, but considering the number of stoppages that had occurred in the cables crossing the Channel, from breakage, or imperfect insulation, he thought the Red Sea cable presented a favourable comparison. He was bound to say, that before the Company adopted the cable recommended by Mr. Lionel Gisborne, (Assoc. Inst. C.E.,) and himself, the Directors consulted Mr. Edwin Clark, (M. Inst. C.E.,) Mr. Cromwell Varley, and Mr. Henley, none of whom, at that time, condemned the iron cable. Some, indeed, proposed a thicker outside wire, whilst others, on the contrary, considered it ample, or even more than sufficient. This cable had been underrun and examined for many hundred miles; and it was not found to be corroded to the extent which had been imagined. The report stated, that after one year's submersion, the strength of the cable had not, as a general rule, been diminished from that cause, more than one-tenth. The Directors of the Company, whose officers superintended the manufacture and the laying of the cables, were now endeavouring to throw the entire risk upon the Contractors.

With regard to the Rangoon cable, he, in conjunction with Mr. Lionel Gisborne, was intrusted by the Government with that undertaking. The cable was originally intended to have been laid from Falmouth to Gibraltar, and was, therefore, essentially designed for deep water. After mature deliberation and a series of tests, an outer covering of hemp and steel, was recommended for the deepest portion of the sea. This form he had found to possess greater tensile strength, in proportion to its weight in water, than any other cables he had tested, and it also had, in his opinion, sufficient weight to sink and to accommodate itself to the inequalities of the bottom. That class of cable had received the approval of Sir Charles Bright and of the late Mr. Robert Stephenson. The destination of this cable was afterwards changed to Rangoon and Singapore, but the iron-covered portion of it, which had been designed for depths not exceeding 600 fathoms, had then been in part manufactured, and could not be altered; however, as the whole cable was iron-covered, and the main portion of the line was removed from any anchorage ground, he thought that, upon the whole, it was well suited for its destination. The shore ends were thick and heavy, and the precaution was always taken to lay them at a great distance from land, in two instances as much as 50 knots, and when the line approached a spot in which ships were likely to anchor, a thick cable was inserted. The tensile strength of the cable was great, and the iron was not so thin as had been represented. For great distances, however, a comparatively light cable must, necessarily, be employed, for it would be too expensive, in order to avoid occasional injuries, to lay down a cable weighing from 6 tons to 8 tons per knot, through the whole distance of 3,500 miles. Had that system been adopted with the Red Sea cable, it would have increased the cost to four times the amount. The line from Toulon to Algiers, had also been intrusted to them by the French Government, and the cable was made exactly upon the same principle as that already described, for the deep-sea portion of the original Gibraltar line. He was not present when it was laid, but he understood, that it payed out with great ease and with little strain; and on one occasion, when a 'kink' occurred, the cable was hauled back for three miles, out of water 1,600 fathoms deep. He ventured to say, that such an operation could not be effected upon any other cable, hitherto laid, with as much facility, or without great risk of fracture.

Of all the systems adopted for testing cables, he thought that of Messrs. Siemens was the best, and was the only one which gave a true description of the cable, for all the figures, when reduced to a certain standard, represented the state of every portion of the cable. It would, probably, save the Rangoon cable from arriving at its destination, in a condition unfit to be laid, and it was to be feared, that other cables had materially suffered by not having been properly tested. There was no reason, however, to believe, that the Rangoon cable had suffered the slightest injury.

In answer to questions from the President, Mr. Forde said, he was present during the laying of the cable between Aden and Kurrachee, but, he must decline stating how far he and his agents were allowed to interfere, or whether the cable was loosely, or tightly laid, and under what strain. He had worked the line, by means of translation, from Aden to Kurrachee, at very good speed, but the whole distance from Suez to Kurrachee had not, to his knowledge, been worked throughout.

Mr. FREDERICK BRAITHWAITE said, having been engaged in the inspection of a cable, 240 miles in length, for the Government of Tasmania, he had come to the conclusion, that so long as the cable was covered with wire, whether light, or heavy, its durability was only a question of time. It would be in the recollection of many, that the portions of the Atlantic cable which had been protected from the action of the sea water, came up as bright and as perfect as when they were laid down, whilst iron cables of large dimensions, had been totally destroyed by the action of the salt water. He was sorry so little attention had been paid to the testing of cables under water, previously to laying them. In the case of the Tasmanian cable, Mr. Latimer Clark directed, that it should be submerged as soon as possible after it left the reel, and a tank was provided for that purpose. One day, a fault was detected, and on tracing back, it was discovered to be in a portion of the cable which had been made four days previously; showing the great probability, that the fault would not have been detected, without submersion. He ordered diagrams, with accompanying tables, to be made, showing the temperature of the water, night and day, and also the effect of the working of the cable so submerged. But with all these precautions, he was afraid, from its having been covered with unprotected iron wire, that it had already shared the fate of other cables similarly constructed. So long as Engineers were not agreed upon any one single point relative to the construction of cables, little progress could be hoped for in submarine telegraphy.

Dr. WALLICH believed, that there were no obstacles in laying down cables, which could not be overcome by the engineering science of the age; but he would draw attention to the very imperfect manner, in which surveys of the bottom of the sea had, hitherto, been conducted. In no single instance, had there been a survey of a character sufficiently complete to render the submerging of a cable a safe operation, or to afford data whereby it was possible to ascertain, with any degree of accuracy, the nature of the bottom, throughout any given line. It was almost needless to state, that in these undertakings, instead of determining by survey the most eligible route, its selection had often been made the preliminary measure. In one instance, the Engineer had actually arrived with the cable, at the scene of operations, before he was made acquainted with the nature of the bottom on which it was to be laid. It was customary, in surveying shallow portions of the sea, to take soundings at moderate intervals, and as deep water was approached, those intervals were extended. In an examination of the records of surveys, he found, that in deep water, the mean interval of the soundings was twenty miles, and, therefore, the elevations and depressions by which the contour line of the bottom was estimated, depended upon observations, taken at those intervals. Now on the Valentia side of the Atlantic, a dip of 7,200 feet had been ascertained to exist in ten miles, or at the rate of 720 feet per mile, and near the east coast of Greenland there was another dip of 3,468 feet in three miles and a half, which was at the rate of 1,000 feet per mile. It was evident, that in these instances, unless soundings were closely continued in one, or both directions, very inaccurate estimates of the true extent of the dips might be arrived at.

Thus in the proposed line from England to Labrador, there would be no certainty, that the excess of depth,—400 fathoms,—asserted as occurring in the mid-Atlantic route, might not be surpassed. He did not believe, that great depth alone would endanger the safety of a cable: for the greater the depth, the less would be the amount of animal life and the changes of level. The recent examination of the North Atlantic line showed that, near Iceland, there was a series of abrupt elevations and depressions at short intervals, producing a saw-like disposition of the surface, which was composed of volcanic rock that never lost its abrasive character, or the angularity of its particles. In the operation of sounding, much depended upon the apparatus; in the survey of the 'Bull-dog,' some new forms of sounding apparatus had been employed which surpassed in efficacy those previously in use.

In answer to questions by the President, Dr. Wallich stated, that he was present at the survey between England and Labrador, which happened to have been made during an exceptional season, in which no cable could have been laid off Greenland; otherwise, he had not observed any difficulties, which might not be surmounted by engineering skill. The possibility of laying a cable by that route, entirely depended on the accident of weather. The survey which had been made, indicated the necessity for a more perfect and close series of soundings, especially near the coast of Iceland, than those taken from on board the 'Bull-dog.' However efficient the old system might be for navigation, it was almost useless for the purposes of submarine telegraphy.

Mr. West observed, that gutta percha had, hitherto, been considered the sole material for insulation; but recent experiments undertaken by the Government had shown, that india rubber possessed high insulating power with extraordinary low specific inductive capacity, great flexibility, and elasticity. There was, however, one point which the Government experiments could not, and which time only could test; its durability. As a proof of its qualifications in this respect, Mr. West exhibited a specimen of wire insulated with india rubber, which had been used, experimentally, between

H.M.S. 'Pique' and 'Blake,' in the year 1845, and across Portsmouth Harbour, in the following year; also, a large coil of wire so insulated. In these cases, the india rubber had remained perfectly durable and hard, while the rope yarn, which had been well saturated with tar, over which these insulated wires had been laid, had become decomposed; the tar had disappeared, and the rope yarn had lost its tenacity and had become rotten. He was of opinion, that the failures of the Atlantic, of the Red Sea, and of the Rangoon cables, were attributable to their want of proper insulation. It was well known, that from the porosity of gutta percha, which admitted a slow transudation of fluids through its mass, chemists could not use it, when made into bottles, or other vessels, for the purposes of holding their chemical fluids. It became, therefore, a question for serious consideration, whether more caution ought not to have been used, before this material was selected by those who were intrusted with the management of these cables, at an expenditure of more than £1,000,000 of the public money.

Mr. **SAWARD** remarked, that the discussion appeared to have diverged from the original question of the causes of failure in submarine telegraph cables. It would seem to have escaped notice, that there already existed no less than about thirty separate undertakings in submarine telegraphy, owning, in the aggregate, about three thousand miles of cable, a large proportion of which had been completed and at work during many years; and some of which, though more recent, had been successfully laid in deep water. These cables had, hitherto, remained in almost perfect working order, having cost an inconsiderable percentage in maintenance, since submersion; and it was remarkable, that all of them, except about one hundred miles, had been made and laid by one manufacturer. Some of these cables appeared to him to afford a fair basis for reasoning upon the causes of failure, at least in shallow water, and he would afterwards glance, separately, at the failures which had taken place in deep-sea cables.

The first successful cable was that between Dover and Calais, which was laid in 1851. It was strongly constructed, and it was protected with thick iron wires of the best quality; and, having been so successful, it might have been taken as a model for future cables in shallow waters. It was so considered by some Electrical Engineers, and the cables they had designed had also been successful, as for instance, those between Portpatrick and Donaghadee, between Portpatrick and Carrickfergus, and between Dover and Ostend. But a desire of originality and of innovation upon established practice was soon evinced, in the first cable laid between Holyhead and Dublin. That cable was made on his own private account, by an eminent Contractor, who, moreover, was at the very time, under contract to a public company, to make and lay a large cable between Portpatrick and Donaghadee, to which, if successful, his own would have proved a serious rival. This cable, however, which was very slender, lasted only about twenty-four hours after submersion. Then followed the Irish lines of the International Telegraph Company, and the galvanised iron cable from Orfordness to the Hague, all cables of small dimensions and of limited strength, the failures of which seemed to establish the fact, that these changes in the character of cables had been made, without due regard to the risks of breakage, from anchorage and other causes. He was glad to find, that in the last cable of the Electric Telegraph Company, they had returned to the old model; and he was convinced, that if that were adopted for the Irish, and for the Channel Islands cables, the failures would become exceedingly rare. He considered, that in shallow waters, the thickness and strength of the cable ought to be limited only by the power of the machinery to lay it, and the ability of the projectors to pay for it. He would further observe, that for cables in the seas around Great Britain, additional security might be obtained, by careful surveys of the bottom, with the view of selecting the most suitable places for depositing them. He would also suggest, that the best iron only should be used for the exterior covering, as wire varied considerably, according to its quality, in the time required for its oxidation. This became an important consideration in shallow waters, where the cables had, occasionally, to be lifted on account of damage.

In deep-sea cables, there had, unfortunately, been little else than failures, the causes of which were apparent, and which fell, perhaps, rather within the scope of the moralist and the man of the world, than of the man of science. The details of the Atlantic cable were arranged before anything was practically known about deep-sea cables; the route was sounded and examined, even more than, in those days, was thought necessary, or had been the practice; the cable itself, was designed upon the last and most enlightened principles of that time; and if such a cable were constructed under proper supervision, he believed it could be laid, even at the present day, with facility, and with a probability of lasting success, although the conductor, owing to its small size, would never have worked with the rapidity that could now be easily attained. But a great mistake was made from the first, in the mode of organising the undertaking; there was a Provisional Committee, consisting chiefly of the promoters and expectants of office under the Company, and these not only decided upon the form of cable, but they entered into and completed the conditions of the contracts for making it. The contracts were given to two rival manufacturers, at the very time in litigation with each other, one-half of the cable being made in London, and the other half in Birkenhead. The result had been, jealousy, carelessness, shifting of responsibility, want of supervision, and impossibility of properly testing the cable; and the final catastrophe might easily have been predicted from such a commencement. The abnormal forms under which portions of the cable, examined since the cessation of working, had been found, afforded sufficient proof of the correctness of his assertions. The radical fault, no doubt, was the precipitate manner in which the contracts were let, whereby the Board of Directors, subsequently appointed, were precluded from appropriating any portion of the funds of the Company towards preliminary practical experiments, or from exercising that control over the proceedings, which would, otherwise, necessarily have occurred to them. Nor could they even postpone the laying of the cable, without breaking faith with the shareholders and the public; for the promoters were also the persons who had raised the capital, and they had pledged themselves to make the attempt in 1857.

The Red Sea cable was another instance in which a disastrous waste of money had its origin, in other causes than scientific difficulties. After the concession had been purchased, and a liberal arrangement had been made with the Company by the British Government, which should have rendered the property very valuable, it was found that, owing to certain complications, the Directors had also acquired an Engineer and a Contractor, who had secured all the concessions that could be obtained in Constantinople; that, practically, the form of the cable was already decided upon, and that little remained for the Board but to furnish the money. Although, at the instance of Lord Stanley, a specimen of the proposed cable was shown to several scientific authorities, this was not done, until its form had become a foregone conclusion, as the contract for its manufacture had already been entered into. The Blue Book showed, that there had been previous dealings between the Engineer and the Contractor; the concession for an important portion of the route, that between Constantinople and Alexandria, had been already sold to the Contractor for the Red Sea cable, and thus it was considered imperative to give the latter contract to Messrs. Newall and Co., at a higher price, as they alone could promise a direct through communication with England, by a stated time. The contract was wrong in principle, as it was taken for a certain fixed sum, limiting the length of the cable to 3,800 miles, thereby offering a premium upon the chances of saving some part of the slack, or surplus, cable. That fact, probably, more than the unsuitable nature of the cable itself, had caused the failure, as there was reason to believe, that the fractures were occasioned by the tightness with which the cable was laid; and he had understood, that several attempts to repair it had been frustrated, from the same cause. Having touched upon the chief points relative to the two principal deep-sea cables, he thought it unnecessary to examine into the causes of the failures in the Mediterranean and elsewhere. He hoped, that these observations would have the effect of leading men of eminence in scientific and mercantile pursuits, to the latter of whom these cables were of great consequence, to consider carefully the whole subject, and in so doing, they would satisfy themselves, that submarine telegraphy was not an enterprise involving so much risk as had been supposed, and that by careful and continued supervision, success might, in most cases, be obtained.

With regard to the Rangoon cable, he thought the core was the most perfect which had yet been made, and it was to be regretted, that a perilous experiment had been made upon so valuable a property. If the surrounding wires had been saturated with tar, as had always been the practice with former cables, he apprehended the heating could not have taken place. In the case of the Rangoon cable, however, every particle of tar was pressed out of the hemp, before it was wound round the core. When it had received its iron armour, it was placed in water, out of which it was subsequently taken, without passing the bright iron wires through tar, or any other mixture to prevent oxidation, and it was coiled up wet in the hold of the ship. It might, possibly, have been imagined, that the dry yarn would prevent the tar from forming an insulator round the core, to such an extent as to conceal, temporarily, a fault in the gutta percha. If such was the case, the arrangement was, in that sense, to be approved of, proper precaution being used in other respects. He thought great and useful changes in the intervening covering between the core and the outer wires of cables, were likely to result from the experiments recently carried on by Mr. Willoughby Smith, at the Gutta-Percha Works. But if it had been deemed proper to leave the yarn dry, for testing purposes, this ought not to have prevented proper precautions being taken, for preserving the outside wires from oxidation; for to this oxidation and the consequent recall and detention of the ships, the subsequent disasters to the Rangoon cable were mainly to be traced.

In order to be able to compare the respective merits of india rubber and gutta percha, as insulating media, it would be necessary, that the qualifications of the former should first be tested, by laying down short lengths in the sea, and allowing them to remain there for two, or three years. The capabilities, as well as the defects of gutta percha, were fully known; portions of the original Dover and Calais cable had been brought to the surface, after nine years' submersion, and they were found as perfect as when first laid down ; indeed, the texture was closer than that of new material. On the other hand, the very imperfect trials that had, as yet, been made with india rubber, had not proved favourable; those, therefore, on whom rested the responsibility of advising the expenditure of large sums of money, could have no hesitation in giving the weight of their recommendation to the tried, rather than to the untried material, especially in carrying out a long line of cable.

Mr. FLEEMING JENKIN was present when the cable was laid between Alderney and Portland. The route, he was told by Mr. Newall, had been selected by the Government. He wished to be informed, whether the first fracture of the cable, described as due to the sand having been washed away, was supposed to have resulted from a strain upon the cable, or from the motion caused by the tide and waves; whether in the fourth fracture, (Table I., page 33,) in the shore end, where the cable was much thicker and stronger, any signs of corrosion were visible; also what evidence there was, that after some of the wires had been worn through by abrasion, sufficient elasticity had remained in the cable to sever it. He believed the cable had been payed out with a strain of about 15 cwt.

The cable between the Island of Sardinia and the coast of Africa, belonging to the Mediterranean Company, was laid down in the year 1857. In 1858, it became necessary to repair it, and he accompanied Mr. Liddell, one of the partners of the firm of Messrs. Newall & Co., to the spot, for that purpose. A length of about 30 miles was picked up, from the Sardinian end, and it was again successfully replaced. Within the last few months, the cable having completely failed, he was employed by the Mediterranean Telegraph Company to repair it. Testing showed the existence of faults, about 40 miles from Sardinia, and also, that the cable was broken at about 5 miles off the African coast. On picking up the cable at the African shore, he found that the shore end was uninjured by corrosion, but as soon as the smaller portion of the cable was reached, it broke in the same depth of water, during the attempt to lift it. He then grappled beyond, and at last, he came to the original fracture, which he believed to have been caused by the trawls of the coral fishers, after the outer wires had been corroded. An extensive coral fishery existed on that part of the coast, and its grounds were crossed by the cable, showing the little care that was formerly taken in the selection of a route. Beyond this fracture, the cable was discovered to be again broken, at the distance of 2 miles. The whole of the smaller cable, near Africa, was corroded; it was covered with marine animals, and much coral was found deposited on it.[1] The second fracture was due to corrosion and to the coral fishers, as in the previous instance. Beyond that point, the cable was so much corroded, that it broke during the operation of lifting, in 70 fathoms of water. The sea end, however, was found, and he ascertained from testing, that some of the wires were good, up to about 40 miles from Sardinia, but not the faintest signal was received. Sound cable was then laid to the African shore. He afterwards picked up the cable from the Sardinian end, and the first 39 miles were as sound as when it was first laid down; in some specimens, no rust whatever was apparent, and the section of the wire was not, in the least degree, altered. At this distance from the shore, there was a change in the nature of the bottom, evidenced by the different colour of the mud; and the wires were much corroded. Shortly afterwards, the cable broke in a depth of 1,200 fathoms, at a distance of one mile from the spot, where the electrical tests showed, that the cable had previously broken. Thus the previous fracture, which had stopped the working of the cable, had occurred at the above depth, as the cable lay, apparently, undisturbed, but with the wires greatly corroded. This did not amount to a positive proof, that in deep water a cable must, necessarily, break, if the outer covering was corroded, but he thought it would be dangerous, after such a precedent, to lay down an unprotected iron-covered cable in deep water. With those 40 miles of cable, much coral and many marine animals were brought up, but it did not appear, that their presence had injured the cable, for they were attached to the sound as well as to the corroded portions. Specimens of the rust from the cable had been submitted to analysis, which did not afford any evidence that the decomposition of the animal matter had led to the corrosion. There was corrosion near the African coast, but none near the Sardinian coast, although rocks and animals were found near both. The cable, where it was uncorroded, had not been buried in mud, as was proved by the short, fine seaweed upon it. The cable was covered with eighteen wires

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[1] The following is a list (1–15,) of the marine animals attached to the cable :—
1. Salicornaria, one of the Polyzoa.
2. Egg of a Dog-fish, attached to a specimen of Alcyonium. [3. Retepora,

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3. Retepora, one of the Polyzoa.
4. Ova of some species of Cephalopod. In several of these ova, the embryo was visible, and proved to belong to the family of the Sepidæ. Found at a depth of from 70 fathoms to 1,200 fathoms.
5. A zoophyte belonging to the family of the Gorgonidæ.
6. Granlia, one of the Sponges.
7. Alcyonium, one of the Actinozoal Zoophytes.
8. Ascidia, one of the Tunicated Mollusca.
9. Cellepora, one of the Polyzoa.
10. Caryophillia, one of the true Corals. Found at the depth of 1,100 fathoms.
11. Sabella, one of the Tubicolous Annelides.
12. Plumularia, one of the Hydrozoal Zoophytes.
13. Lima, one of the Lamellibranchiate Mollusca.
14. Serpulæ, the animals and their tubes, belonging to the Tubicolous Annelides.
15. Eschara foliacea, one of the Polyzoa.

of No. 11 gauge, similar to that adopted for the Rangoon cable, but it appeared, that wire of that gauge was not a sufficient protection. He was ignorant of the cause of the fracture, in deep water, of the Bona cable, but he imagined it was due to the elasticity of the cable, which, having been laid too tight, severed the core after the decay of the outer covering. He had inquired what evidence there was of this having occurred in the Channel Islands cable, because he wished to apply to failures in deep water, the explanation which had been given by the Author, of the failures in shallow water.

The first remedy for these disasters appeared to be the employment, in shallow waters, of wire of a larger gauge. The evidence, that the thinner portion of the cables corroded, whilst the shore ends remained perfect, was in favour of that plan. An instance of the kind was afforded by the Spezia and Corsica cable, but perhaps, the ground crossed was favourable. The difficulty of paying out a cable of large wires from small drums, had been exaggerated, for he had payed out, with facility, a cable 1½ inch in diameter, from a drum 6 feet in diameter. But for a long deep-sea cable, it was impossible to adopt heavy wire coverings, on account of the number of ships which would be required for its conveyance. A second remedy was to coat the external wires with some bituminous composition, which would not injure the gutta percha by heat when applied, and was not too expensive in its application. A third remedy which had been proposed, was to make careful soundings of the bottom, along the route where the cable was to be laid, but until the particular character of bottom which caused corrosion was better known, this remedy could not be relied on. A fourth possible remedy might be, the adoption of a light cable not covered with iron wire; because, although at the present time, the general feeling was in favour of heavy cables, in consequence of the failure of small iron-covered cables, there was no evidence to show, that cables quite unprotected by iron wire, would also fail. An unprotected cable would be free from the dangers arising from being laid too tight; for the weight and elasticity of the iron covering had been found to add to the insecurity, when, from any cause, some particular part was weakened. He would also remark, that there were no marks of abrasion on any portion of the cable between Africa and Sardinia, and that, therefore, to all appearance, an unprotected cable might have lasted uninjured in deep water.

The failure of the Atlantic cable was due to defective supervision and imperfect construction, and even if it had succeeded in the first instance, it would, probably, have failed, after a short time, from corrosion; but possible failure from this cause, was not generally suspected at that period. The Malta and Corfu cable, of somewhat similar construction, lasted for eighteen months, and during the time it was in operation, the Red Sea cable was designed. The discussion upon the Paper by Messrs. Longridge and Brooks, in 1858, chiefly turned on the comparative merits of light and heavy cables: but corrosion, he believed, was not once mentioned, on that occasion, as a source of danger to cables. As a further proof, that men of experience did not, at that time, foresee the danger of corrosion, Messrs. Newall & Co., in the same year, 1858, made a cable for their own line in the Levant, of very similar construction to that used for the Red Sea. As the Levant lines belonged, principally, to Messrs. Newall & Co., and were worked by them, they, at least, must have believed that form of construction to be durable. It was, however, singular, that the Levant cable should have proved an exception to the general law of destruction. All the sections of that cable which were laid, still remained in working order; that is to say, the sections between the Dardanelles and Scio, between Scio and Candia, between Scio and Syra, between Scio and Smyrna, and between Syra and Athens; in all, about 600 miles.[1] On the other hand, since 1858, many instances of corrosion had occurred in the Atlantic, in the Black Sea, in the Mediterranean, and in the Red Sea, and also near the English coasts. For these reasons, he believed, that it would be unwise to send a light iron-covered cable, such as the Rangoon cable, to a distant part of the world, without further protection. It had been shown, that cables of a somewhat similar description, had failed in deep water, after the corrosion of the outer wires; and in shallow water, there was still greater risk of failure, for it was difficult even to avoid the danger of laying it too tight. To lay it slack in 30 fathoms, or 50 fathoms of water, the tension required was so small, that it was scarcely sufficient to draw the cable out of the hold of the vessel; at all events, with the machinery to which he had been accustomed.

Passing to the the electrical part of the Paper, Mr. Jenkin observed, that he preferred Wheatstone's bridge, especially as arranged by Messrs. Siemens, Halske, & Co., to the instrument described by the Author. It was stated, that the charge was inversely proportional to the ratio of the external and internal diameters of the gutta-percha coating, but Mr. Jenkin believed the charge was inversely proportional to the logarithm of that ratio; neither did he consider, that the charge was proportional to the surface of the copper conductor. The reduction galvanometer of the Author assumed the battery power, and the magnetism of the needle, to be both constant; an hypothesis which could not be granted. Having observed the water current described in the Paper, he did not think, that where the resistance of the cable formed a large part of the circuit, the deflections given by the water current could be of much use in determining the distance of a fault, or the amount of copper exposed; the deflection produced, depended on two unknown quantities, the resistance of the circuit, and the electromotive force of the copper and iron voltaic couple at the fault.

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[1] Several of these cables have since required repair.—F. J. March, 1862.

He had frequently remarked the so-termed 'gas currents,' caused by what was commonly called polarisation, and he had also found, that these currents interfered with observations of the discharge, or return currents in short cables, and in longer cables when small battery power was used. Messrs. Siemens had pursued an independent investigation of the electrical phenomena connected with submarine cables, but having obtained their valuable results unaided, seemed not to be aware of what had already been done by others. The practice of expressing the resistance of gutta percha by units of resistance, was introduced, in 1857, by Professor W. Thomson, at the British Association in Dublin, when he gave the specific resistance of gutta percha, with considerable accuracy. At the suggestion of Professor Thomson, Mr. Jenkin tested the Red Sea cable in such a manner as to express its insulation, in terms of the resistance of the gutta percha, and in 1859, he communicated the result to the British Association, at Aberdeen,[1] giving a value to the specific resistance of gutta percha, which corresponded to a resistance per knot, of 94 millions of Messrs. Siemens' units, at 60° Fahrenheit. He had published, at the same time, temperature curves derived from actual experiment upon various lengths of gutta percha, and he also mentioned the great influence of continued electrification which, he thought, had not been attended to in the system of Messrs. Siemens. Complete details of his experiments had been read at the Royal Society in 1860,[2] and the specific resistance of the gutta percha at 75°, then given, was equivalent to a resistance per knot, of 46 millions, after one minute's electrification. His measurements were not made with Wheatstone's parallelogram, but by angular deflections. It had been asserted, that angular deflections would not give correct results; but if instruments of precision were employed, such as tangent, or sine galvanometers, and care was taken to measure the battery resistance and electro-motive force in each instance, then angular deflections might be used to determine the resistance of gutta percha, in units; and they formed, in some cases, the most convenient method of obtaining that resistance.

It might be asked, if the Red Sea cable was so well tested, and if its insulation had been so accurately measured, attention being paid to variations in temperature and all other disturbing causes, why should faults have occurred in the cable, when it was laid down. The reason was simple: the cable had not been immersed in water during the tests. He had long been aware, that unless the cable was immersed, a fault could not be detected; but so far as the resistance of gutta percha, and the investigation of the qualities of that material were concerned, he had not found, that immersion was of consequence. If the cable was sound, and the temperature remained the same, the test of the gutta percha would be the same, before and after immersion. The reason the cable had not been immersed, was the fear of oxidation of the outer wires; but that was not a sufficient excuse for the omission, because the cable should have been so constructed, as not to be liable to injury from that cause; and to send abroad a cable which Electricians dared not properly test, seemed an act of folly.

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[1] *Vide* "On Gutta Percha as an Insulator, at various Temperatures," by Fleeming Jenkin; in the "Report of the British Association," 1859. Transactions of Sections, p. 248.

[2] *Vide* "Proceedings of the Royal Society of London," vol. x., p. 409.

With regard to the heating of the Rangoon cable, he had tested many cables which had been, alternately, in and out of water, some which had been picked up from the sea, and others which had been immersed at Messrs. Newall & Co.'s works, but, hitherto, he had never discovered any heating. He generally placed in the centre of the coils, thermometers in tubes, which would not have failed to detect heating, if it had occurred; and in cases where thermometers had not been used, the change in insulation, consequent on the change of temperature, would, certainly, have drawn his attention to this fact. He attributed the absence of heating in the cases alluded to, to the hemp having been saturated with tar, and each coil of cable having been well coated with it.

The insulation of the Rangoon cable, being 100 millions of Messrs. Siemens' units per knot, was very high: the resistance of the Red Sea cable gave only 46 millions of units, at the same temperature. Now the ratio of the internal and external diameters of the gutta-percha covering was nearly the same in the Rangoon, and in the Red Sea cables; the Rangoon cable, therefore, tested, at the temperature of 75°, better than the Red Sea cable, by more than double. It would be desirable to know whether any portion of the Rangoon cable which had been overheated, had returned to its original condition, and whether the resistance, when it cooled down, was as high as it had been before the heating; because he had found, that gutta percha deteriorated, although not so much as to make it useless, within the limits of 1 and 10. The gutta percha of the 40 miles of the Bona cable which he had lately picked up, was all sound, and there was no difference between the portions in deep and in shallow water. The specific resistance was not, however, so high as in cables, when recently made, although he had found that some cables, shortly after they were manufactured, would fall lower than others which had been three years under water. This variation rendered the testing of a cable a very delicate matter, unless the electrician had been well acquainted with the cable when it was first made.

With regard to the question of units, it was desirable to introduce a system which should be invariably adopted; but it was not a matter of indifference which units were chosen. Messrs. Siemens had taken an arbitrary length and a section of an arbitrary material; owing, however, to the judicious choice of the latter, this unit could easily be reproduced. But now that the relation between electricity and mechanical effect was understood, it was possible to express electrical values in units, depending directly upon the absolute units of force. Not only could electrical resistance be so expressed, but also the strength of a current, the electro-motive force of a battery, and the quantity of electricity. Units so chosen, did not depend upon an arbitrary assumption of some one quantity for unit, of the same nature as the thing to be measured, but upon the relation between the mechanical effect and the different forces. This system of units was first proposed in 1851, by Weber, in Germany, and shortly afterwards, Professor W. Thomson proposed its adoption in England. The absolute unit of resistance which he gave was such, that about 30 millions were equal to one of Messrs. Siemens' units.

In answer to a question, Mr. Jenkin said, that in the large number of cables he had raised, he had never observed any electrical action between the copper wires and the gutta percha, to which the destruction of the cable might be attributed.

Mr. Willoughby Smith said, that being anxious to elucidate the causes of failure in submarine cables, he had tried many experiments, from which he thought he should be able partly to account for several of the failures that had taken place.

In the first experiment, a length of core, having the conductor exposed in four different places, which were afterwards covered with hemp, saturated with Stockholm tar and tallow, so as to represent, as nearly as possible, the core of a cable after it had passed through the serving machine, was immersed in water, and the insulation remained perfect for three days, the test being frequently applied from a battery of 504 pairs of plates. This length was then joined to a line eight miles long, and again immersed. The line was kept charged from a battery of 504 elements, (the current being reversed 400 times each minute,) for a period of 468 hours, during which time the line was frequently tested for insulation, and some curious results were obtained, owing to the varying amount of resistance offered by the tarred yarn. The line had now been 172 hours uncharged, and when again tested, the defects offered so little resistance, that only 108 elements could be used.

In the second experiment, five nails, passing through the strand conductor, were forced through the gutta percha, in a length of core, which was then served with hemp, saturated with tar and tallow. This was immersed and remained perfect in insulation, for 168 hours, the same battery power and instrument being used as in the first experiment. At the expiration of 192 hours, the fault had become so bad, that were it to be charged with reversals for 24 hours from a strong battery, continuity would be destroyed.

In the third experiment, another length of core was prepared in the same manner, but the nails were withdrawn, previously to being served. This length had been immersed during 676 hours, yet the insulation was still perfect. These results clearly proved, that the failures of submarine cables, after working successfully for various periods, had not been caused by any deterioration of the gutta percha, but by the injuries to the core, which had been temporarily concealed by the tarred serving.

It had already been stated, that a fault was discovered in the Tasmanian cable, at a part which had only been manufactured four days previously; and he recollected an instance of a cable having been submerged, during six weeks, on the manufacturer's premises, yet the fault was not detected till a few days before its final submersion. This danger might be obviated by saturating the serving with a conducting, instead of an insulating fluid, thus keeping the core constantly under an electrical test.

Serious apprehensions having been entertained, that the core of the Rangoon cable might be damaged by the heat generated on ship-board, he had made the following experiments, with a view to ascertain the degree of heat which would affect the core. A length of the same sized core as that of the Rangoon cable, was wound on an iron cylinder, 12 inches in diameter, and was immersed in water at 100° Fahrenheit, during two months; at the expiration of which time, it presented no signs of alteration. One nautical mile of the same sized core had also been immersed, at the same temperature, for 676 hours, and it was now as perfect in every respect as at first. Two lengths of a smaller-sized core had already been immersed at the same temperature, during 1,102 hours, the insulation tests being taken with a battery of 504 pairs of plates, and a very sensitive galvanometer. These lengths had not, as yet, shown any deterioration, but a gradual improvement in insulation; no doubt need, therefore, be entertained of the Rangoon cable, so long as the temperature did not exceed 100° Fahrenheit. The increased resistance of gutta percha by long immersion, was also very remarkable at low temperatures.

Mr. Edwin Clark would not assert, that a heavier cable between England and Holland might not have possessed some advantages; but the cables alluded to by Mr. Saward were, really, the first long cables that were attempted, and when they were laid down, there was little experience to guide the Engineer. The only cable previously in use was that between Dover and Calais: and it was then almost impossible to have laid down a cable of that weight, over a distance of 100 miles, even had it been thought desirable. He might state, that great difficulty was experienced in finding a steamer capable of carrying a cable weighing only 1¼ ton per mile, for it was not every vessel that was available for such purposes: this was not, however, the only motive for adopting four light cables, instead of one heavy one. It was considered, that as some risk attended the paying out of the cable, the loss of a single wire would not be so serious as the loss of the whole. It was also considered, that in a shallow sea where so many vessels were constantly passing, these cables would, in spite of every precaution, be liable to damage from anchors, while there were many chances against the whole of the four cables being simultaneously injured. These light cables were not only advantageous from the facility with which they could be laid down, but also from the ease with which they could be taken up, if required to be repaired, or renewed. The necessity of constant repair and renewal was always calculated upon, as an element in the first estimate of cost. With respect to the electrical part of the subject, no difficulty existed with regard to the core; a good cable might be made either with gutta percha, or india rubber, as both might be relied upon. But laying down a cable was attended with many difficulties, which had great weight at the early period of their history. The repair and renewal, however, were the salient points which determined the size adopted, and it was still a question, whether any more economical method of insuring a constant communication, could be adopted. These cables had not failed from metallic corrosion: the wire was, even now, but little corroded. The only interruption to which they had been subject was caused, as had been foreseen, by damage from anchors, the cables being laid in a sea traversed by so many ships, and from their lightness, being frequently lifted out of the water. In some cases, the cable received no injury, but in others, it was either wilfully, or accidentally, much damaged, or broken. The Hague cables, he believed, had never failed from any other cause; they had been as successful as any that had been laid down, and even now, they were working well. Although a larger cable had since been laid alongside, it also had already been several times broken from the same cause, and the repair and renewal became a much more costly operation, while, at the same time, the whole communication was stopped, as all the wires were broken. On this account, especially, the maintenance of several small cables was cheaper than that of a single heavy cable; and a stock of small cable was always kept ready at either end. With a single line, the repair, or renewal, required but little time, and only simple apparatus; and no instance had occurred of the four cables being all simultaneously broken.

Mr. C. W. Siemens, in answer to the President, said that recently, the 'Queen Victoria,' which carried the Rangoon cable, had been wrecked, and the hold being filled with water, the cable was now cool. It was about to be transferred to other vessels, and he should again carefully watch it. The temperature, at present, had descended to below 60°, and the insulation was very perfect. His experience had not been the same as that of a previous speaker, for he had invariably found, that after a cable had been once heated, it never returned to the same perfect state of insulation as before; implying that some slight change had taken place in the constitution of the gutta percha, which had not, hitherto, been well ascertained. He would also observe, that less tar than usual had not been used in the Rangoon cable, for the sake of facility in testing; if it was made dryer than other cables, it was for a reason entirely unconnected with the department of the Electrician.

Mr. Daft,—through the Secretary,—said, that during practical experience of many years, he had invariably found india rubber to decompose, when in its natural state, and in contact with brass, or copper, even when a coating of shellac had been interposed, and pressure added to exclude the air.

On the introduction of the process of vulcanising, about 1844, it was applied to washers for steam joints, and he had found it less disposed to decomposition than common, or pure india rubber; still, whenever it came in contact with copper, or brass, it was prejudicially acted upon. In 1848, he discovered the means of making vulcanised india rubber adhere to brass, and the process was applied with success. India rubber was not injuriously acted upon by a temperature under 300° Fahrenheit; it would withstand a great amount of rough usage, and as copper wire could easily be coated with brass, he believed there was no difficulty in making a cable with the conductor and insulating material, for which india rubber was so well calculated, in perfect unity.

He considered, that some improvement was necessary in the construction of vessels, charged with paying out extensive deep-sea cables. He thought the best form to adopt, would be what he had designated a 'twin ship,' with great length and beam, and with the same angle at the bottom, at stem and stern, which would insure a high rate of speed. A part of the deck between-ships, could be made moveable, to fall from one end and hang aft, at an angle suitable for running out the cable, and if hung on centres at the forward end, the stern end could be lowered by suitable machinery to the water's edge, or even below it, thus forming a gangway for the entrance, or paying out of the cable. Such a vessel could take in cables, or other cargo from the shore, or be beeched in places, to approach which, would be fatal to other vessels, and it would allow of the cable being payed out with steadiness and safety in any weather.

Mr. W. H. Preece remarked, that many facts yet remained to be elicited, before the causes of the failures of submarine cables could be fully ascertained ; the main object, however, of the Paper, had been accomplished. It was divided into three parts ; the first was devoted to the Channel Islands cable, its construction and route, a detailed account of all the accidents that had happened, and the means taken to repair them. In the second portion, he had stated the conclusions at which he had arrived, from his own experience, respecting the failures, and the defects in the construction of submarine cables for shallow waters. The third part contained a description of the methods that had been adopted, for testing the point at which a fault in a cable existed.

The first portion of the Paper, being restricted to a narrative of facts, had excited little criticism. It was, indeed, stated, that the route of the cable, which was admitted to have been the chief cause of the failure of the Channel Islands cable, was not selected by the Contractors, but by the Government. For him, however, it was not a question of persons ; his only object had been to draw attention to the want of proper precaution in surveying routes, before cables were submerged, and he hoped, that the corroborative observations which had been made during the discussion, would have the effect of inducing the Admiralty authorities to give instructions to their hydrographers, that, in future surveys, the bottom of the seas surrounding these islands, should be as carefully depicted, as the surface of the land on geological maps.

In reply to the questions which had been asked, relating to the fractures in Table I., (page 33,) Mr. Preece stated, that in No. 1, the cable rested upon a bottom of sand, which had been washed from beneath it by the tide ; the cable, therefore, became loose, and being swayed backwards and forwards by the tides and waves, was gradually worn, and eventually, broken. Fracture No. 4 was not the result of corrosion, but simply of abrasion, caused by the sharp edge of a rock upon which the cable had rested. The fracture which had occurred in the Bona cable, at a depth of 1,200 fathoms, was not exactly similar, although approaching, to that which he had described. The Channel Islands cable was laid at the bottom, with such an amount of tension that it broke, as soon as its strength was reduced by abrasion. This tension was proved by the ends of the fracture, where every separate wire had been drawn out and broken in a different manner. This fact seemed to show that, in shallow waters, cables should be laid as slack as it was possible, consistent with avoiding kinks. With regard to the causes tending to affect the steering of a ship across tideways, when paying out submarine cables, that subject had been so fully investigated in the Paper by Mr. Webb[1], that it would be unnecessary to make any further allusion to it.

In arriving at the conclusions he had given in the second part of his Paper, he was not only guided by his experience in the Channel Islands, but also by his long connection with the cables in the North Sea and in the Irish Channel, and more particularly, with that connecting the Isle of Wight with the mainland. The failures of submarine cables in shallow waters, did not appear to be due so much to inherent defects in the cables themselves, as to the localities in which they were placed. In support of the contrary opinion, it had been urged, that the Portpatrick and Donaghadee cable, which had been submerged eight years, had never been damaged; but on the other hand, the Dover and Calais, the Dover and Ostend, and other cables equally as strong, had been broken. It was, certainly, very remarkable, that a cable in one locality should break, while a cable of precisely the same construction in another locality, should continue in working order. So again, with regard to the cable connecting Jersey with Pirhou, on the coast of France, which was laid in the latter part of 1859, and which had remained in good working order, while the Channel Islands cable had been broken in five, or six places during the same time; yet a similar cable, 5 miles, or 6 miles in length, obtained from the Submarine Telegraph Company, and laid off Alderney, was found, when taken up a short time ago, to be in a very bad condition. Now if the former, lying between Jersey and France, upon a soft sandy bottom, with no rocks, remained in good order, whilst the latter, which lay upon a rough rocky bottom, very rapidly deteriorated, the only conclusion was, that the cause of the failure must be sought, not in the cable itself, but in the locality in which it was placed. Again, although the Hague cables, which were of the same construction as the Channel Islands cable, had given great trouble, yet a similar cable laid in 1857, on the coast of Norway, had remained in good working order. The Danish commissioner, Mr. Neilson, stated, that the cable was now in as good condition as when it was first laid. The cable between Cumberland and the Isle of Man, which was laid about the same time, and was similar to that used for the Channel Islands, gave way soon afterwards, on account of having been laid upon enormous masses of seaweed, which, by their motion, broke the cable; but after being repaired, it had remained in working order for two years. These facts corroborated his view of the cause of failure, and those who adopted the Portpatrick cable as their model, would find, that if it was laid upon the point of a rock, or was brought to the surface by the anchor of a large ship, it would not last longer than the Hague, or the Channel Islands cables. The duration of that cable was mainly owing to its having been deposited upon a sandy bottom, devoid of rocks, where no ships' anchors could touch it.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xvii., p. 276.

It had been stated, that there were two schools in telegraphy, one which advocated the use of heavy cables, of the type of the Dover and Calais and the Dover and Ostend lines, and another which advocated the use of light cables, of the description used in the North Sea. It had also been said, that whereas all those stout and heavy cables that were first submerged, had continued in working order to the present day, the small cables of the International Telegraph Company only had failed, and that these cables had been reduced in weight, merely for the sake of change. Now it was a curious fact, that the former advocates of light cables were, at present, using the heaviest cables that could be made, for the Electric and International Telegraph Company's last cable was the heaviest ever laid; whereas those who started with heavy cables, were now adopting light ones, for the last which had been laid in shallow water, viz., those to Denmark and Hanover, were essentially light cables. Under these conflicting circumstances, he must adhere to the opinion he had expressed, that cables must be made to suit the varying circumstances of the ground, and that a careful and accurate survey could alone furnish proper data for designing them. A heavy cable should be used for anchorage and for rocky ground, and a lighter cable for sandy bottoms; not one long length of heavy, or one long length of light cable, but a varying cable in weight to suit the requirements of the route to be crossed.

The next point to be considered, was the decay of cables from corrosion, which, according to his experience, was owing to three causes. First, to simple oxidation from water running over the cable; secondly, to the cable lying upon a metallic surface; and thirdly, to a cause which had not been much observed, the formation of vegetation upon the cable. With regard to the last cause, it was a curious fact, that off Portland, the animalculæ and zoophytes which formed upon the cable, rapidly corroded it; whereas between Guernsey and Jersey, a different deposit was formed, which contributed to keep it in perfect condition. From the evidence already obtained, it would seem to be essential, that in the submersion of future cables, some means should be adopted to prevent that rapid deterioration and decay, to which they were, at present, subject. There were objections to the plan proposed by Mr. Latimer Clark, but he thought, that such difficulties could easily be overcome. He recollected, that in a previous discussion, one of the projectors of the Atlantic cable had exhibited an old pistol and the shank of an anchor, deeply encrusted with lime, and expressed an opinion, that such would be the condition in which the Atlantic cable would be found, after submersion;[1] but he must have been grievously disappointed, on reading Mr. Varley's report of the state of that cable off the coast of Newfoundland, where it was so much decayed, as to be useless. The composition recommended by Mr. Preece for covering cables, was that known as Peacock and Buchan's; it had been applied to the bottoms of large steamers, which were found to be, after long voyages, as clean as when the vessels started. He had been surprised, that in the course of the discussion, so little notice should have been taken of the faulty construction of the present heavy cables. He had pointed out in the Paper, that although a cable protected with heavy wires was, when complete, strong enough to bear the strain which the anchor of a ship would be likely to occasion, yet owing to the quality of iron generally used, the wires would, probably, break singly, and thus, eventually, cause the fracture of the whole; such had been the case in the North Sea. The only way to obviate this danger in heavy cables, was to cover them with stranded wires, or two servings of smaller-sized iron wire.

The third part of the Paper was devoted to an explanation of the different systems of testing, from which, as he had purposely omitted all names, it had been erroneously concluded, that he had taken credit to himself for everything he had described. His claim was limited to two instruments only, the 'multiplying differential galvanometer,' and the 'inductometer.' He was not aware, that Mr. Latimer Clark had previously proposed an instrument, similar in principle to the 'inductometer.' No claim, however, had been advanced for the galvanometer, which was the more important of the two. He did not claim the invention of resistance coils, the credit for which should be attributed to Professor Wheatstone, who, in 1843, described them in a Paper read before the Royal Society.[2] They were used by the Electric Telegraph Company before 1852, for the same purposes to which they were applied at the present moment. Their introduction and useful application in England was due, he believed, to Mr. Cromwell Varley; he could not, therefore, accord any credit to Sir Charles Bright, for the invention. He agreed in the opinion, that it was very desirable to adopt some fixed standard for expressing the electrical condition of the wires, and he hoped all Electricians would combine to accomplish that object.

The imperfections in gutta percha considerably affected the durability of submarine cables. It frequently happened in repairing a cable, that on the surface of the gutta percha, there was found a small lump, or a little hole, presenting, sometimes, the appearance of having been produced by a flash of lightning, or the burning of a fusee. These defects were generally, but, in his opinion, erroneously, attributed to lightning. The great enemy to be contended with, in working a cable, he believed to be ozone. When the smallest puncture admitted the least atom of water, the decomposition which took place generated ozone, which was known to attack, in a very rapid manner, all inorganic substances like india rubber, or gutta percha.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xvii., p. 322.

[2] *Vide* Phil. Trans. 1843, p. 312.

With regard to the comparative superiority of india rubber and gutta percha, as insulating materials, the electrical qualities of the former had been proved to be far superior to the other, and the only thing wanting, in order to justify its use for long deep-sea cables, was positive proof of its durability. Now he had under his charge, during several years, an india-rubber submarine cable, connecting Hampshire with Hurst Castle; and also crossing the Yarmouth River, in the Isle of Wight. That cable was made in 1852, for the Submarine Telegraph Company, and was afterwards purchased by the Electric Telegraph Company, who submerged it in its present position; and it was, at present, as durable and as good as when it was first laid down. It fortunately happened, that pure india rubber was employed in making the cable; spurious material had, of late, been introduced into the country, and he believed it was mainly owing to that cause, that india rubber had not, hitherto, gained the position which it deserved.

He thought that, in the construction of deep-sea cables, the greatest care should be taken to insure their retaining their original strength unimpaired; there would be then, no greater difficulty in repairing them at depths of 1,000 fathoms, or 1,500 fathoms, than in shallow water. There was no reason why submarine cables should not be taken up for examination periodically, and, where necessary, be repaired, in a similar manner to the wires of an overground line, or the permanent way of railroads. In such routes as the Channel, or the North Sea, lengths of ten miles, or twenty miles, should be examined, picked up, and relaid, every two, or three years.

He believed, that submarine telegraphy would shortly arrive at sufficient perfection, to preserve the communication unimpaired, for an almost indefinite period. The discussion which his Paper had elicited had not solved the question of the durability of submarine cables; but he felt assured, that it would have the effect of assisting the progress of submarine telegraphy.

Mr. Bidder,—President,—said, that if the Paper and the discussion had exhibited the subject as one of national importance, it had also shown it to be a branch of the profession, the practice of which, up to the present time, had been signally unsuccessful. Upwards of 9,000 miles of submarine telegraph cable had been laid down, of which not more than 3,000 miles could be said to be in working order; so that there were 6,000 miles which were almost useless. This result showed conclusively, that there was either a lamentable want of knowledge on the subject, or some radical practical error, which should be carefully inquired into, with the view of applying a remedy. The present deplorable state of submarine telegraphy, was endeavoured to be accounted for, in Blue Books and other published documents, by reference to causes which practical men could not admit; and the conviction which forced itself upon the minds of unprejudiced persons, was, that the obstacles to success had been more of a moral than of a mechanical nature. The promised Report of the Government Commission on Submarine Cables, would soon appear, and he hoped it would give facts, which would either confirm this opinion, or dispel such an impression. It was understood, that the Report would go fully into the questions of the methods of insulation and of testing cables. These had been already brought within the province of mathematical certainty, yet the application of the results had not been satisfactory; and patents were even recently taken out, as if for the purpose of adding difficulties to processes which were, already, sufficiently complex. He was not perhaps, himself without blame in this respect, having been one of those who contributed £160,000, to secure the original patents for electric telegraphy. But patents had proved the curse of telegraphy, for scarcely was the ink of the agreement for the purchase of one patent dry, before another was offered, which was warranted to supersede all that had been previously accomplished; and he had little doubt, that if it were possible to obtain exact statistical returns, it would be found, that the law officers of the Crown had derived more benefit from those patents, than the public, or those to whom they had been granted. He should have considered testing as the last subject on which a patent could be justified, yet some parties had proceeded by injunction, to restrict others from applying such different modes of testing as had been suggested by daily experience; thus endeavouring to retard the progress of scientific knowledge.

The first considerable failure of a submarine cable, was that of the Atlantic Telegraph Company. It would be remembered, that in a discussion at this Institution, several months before the cable was laid, it had been strongly urged, that the cable should be tested during its manufacture, and subsequently, that it should not be laid until it had been tested under water, as nearly as possible under the conditions to which it would be subjected, when it was deposited in the sea. In violation of all these precautions, the cable was laid, with a strong suspicion of its not being in a perfect state; a capital of upwards of £300,000 was sunk, and the cause of electric telegraphy was seriously jeopardised. It must be admitted, that even if the cable had been perfect when it was submerged, there were natural causes in operation which would, probably, have destroyed its conductibility in little more than twelve months; this, however, could not excuse the recklessness with which so large a capital was risked, without adequate precautions. It had been urged, in extenuation, that the expectations of England and America had been so highly raised by the original promoters, that the Directors of the Company found themselves trammelled by engagements and contracts which left them no alternative; but in such case, it was their duty to have pursued the straightforward course of abandoning their responsibility, until the undertaking was placed in such a shape, as to offer every reasonable probability of success.

The last great failure which had excited public attention, was that of the Red Sea Telegraph. It was not for him to judge of the personal considerations, or the moral ingenuity which had been alleged to be at the root of this undertaking; yet he could not help remarking, that if such causes had been at work, they could not have been more adroitly, or more skilfully applied. Before, however, proceeding further, he felt he had a duty to perform to one whose memory would ever be revered in this Institution. It had been stated, that the sanction of the late Mr. Robert Stephenson had been obtained as to the form of the Red Sea cable. This was probable, as he was always ready to give advice, whenever it was asked; but when responsibility was attempted to be fixed upon him, it became necessary to ascertain to what extent his sanction had been given. Did the gentlemen who consulted Mr. Stephenson as to the construction of the cable, inform him who was to be the Contractor? Did they communicate to him the conditions of the contract, or the restrictions under which it was to be carried out? If they did not do so, his opinion as to the mere form of a piece of cable, given probably in the free communication of one gentleman to another, and not as a professional opinion, with all the circumstances of the case before him, should not be made use of, to shift the onus of failure from the living to the dead.

The Red Sea line assumed more than ordinary importance, because the country was under engagement to pay to the Company, about £36,000 per annum, as guaranteed interest upon an outlay which, up to the present time, was utterly useless, and which did not appear to afford much hope of ever being otherwise. The history of this undertaking, as far as it had been made public, was given in the Parliamentary Papers, on "Telegraphic Communications in the Mediterranean and with India." (1859 and 1860). He would quote from these published documents only; and, without entering into all the minute details, it would suffice to lay before the Meeting the broad facts, whence it would be seen, that moral causes had entered largely into the fate of this unfortunate undertaking.

On the 26th of June, 1858, the following letter was addressed, by Messrs. Glass and Elliot, to the Lords Commissioners of the Treasury:—

"We beg most respectfully to address your Lordships on the subject of the proposed line of telegraph to India, by way of the Red Sea, which project is now under the consideration of your Lordships, at the instance of the Red Sea Telegraph Company.

"That your Lordships may be fully informed of the circumstances which have led to this communication, it becomes necessary to lay before you the following brief history, in connection with the progress of the undertaking, and our connection with the same.

"In the year 1855, application was made to us by Mr. Lionel Gisborne, who represented himself as acting for, and under the authority of Her Majesty's Government, for information to enable him to prepare estimates for the carrying out of a telegraphic line to the East; and on his assurance, that we should be placed in a position to tender for the execution of the work, upon his completing certain arrangements with the Turkish Government, we provided the necessary information, accompanied with many specimens of submarine cables, best suited for the contemplated line, with estimates, &c.; upon which Mr. Gisborne proceeded to Constantinople, and obtained the necessary firman from the Sultan, to lay down the line now under consideration. Shortly after his return to this country, these concessions were placed at the disposal of a body of gentlemen, who formed themselves into a company, (the Red Sea Telegraph Company,) for the purpose of carrying out the lines, under the concessions obtained by Mr. Gisborne. In the month of August last, the Directors called upon us to assist them with information, and afterwards, to tender, for the execution of the whole, or one-half the line; which we did, and a prospectus was issued, founded on this estimate, but an insufficient amount of capital was subscribed, caused by certain statements appearing in the public newspapers, to the effect, that it was impossible to lay a cable in the Red Sea, from its great depth, and other causes.

"In this state of things, we suggested the propriety of an application to Her Majesty's Government, to cause a survey to be made, with a view of testing the truth of these statements: this course was adopted, and the 'Cyclops' was ordered on the expedition, and instructions, forwarded, on our suggestion, to the Admiralty through the Hydrographer, were sent out to the officer in command of the 'Cyclops,' and the result having been highly satisfactory, a further attempt was then made by the Directors to carry out the line; hence the proposal now under the consideration of your Lordships. The undertaking having thus far proceeded, it was found, that the agreement between Mr. Gisborne and the Directors of the Red Sea Telegraph Company had, in the meantime, lapsed by a few days; and on being called upon by the Company to renew the same, he consented, but insisted, as we have been informed, that in addition to the sum of £15,000, agreed to be paid to him in consideration for the concessions, that he should be appointed Engineer to the Company, and that the whole of the work should be given to Messrs. Newall and Company, without tender, Messrs. Newall and Company having become interested with him in the concessions; and he was bound to them accordingly.

"The Directors have felt themselves constrained, under the peculiar circumstances of the case, to submit to the terms imposed by Mr. Gisborne, and a conditional contract has been entered into with Messrs. Newall and Company, approved by Mr. Gisborne, to carry out the work for the sum of £650,000, or thereabouts. The Directors having given us an opportunity of seeing these estimates, we are in a position to inform your Lordships, that we are prepared to execute similar work for £100,000 less than that amount.

"Should your Lordships find, on inquiry, that our statements are correct, we feel sure, that your Lordships will not, under such circumstances, sanction the application of public money to this purpose, for the private gains of individuals to the prejudice of the public."

Upon this there followed a Treasury Minute, dated August 4, 1858:—

"Inform Messrs. Glass, Elliot and Company, that my Lords have made an arrangement with the Red Sea Telegraph Company, by which, on certain conditions, a guarantee on the part of Her Majesty's Government is granted to that Company.

"It is one of the conditions in the arrangement, that the line of telegraph shall be laid down on the responsibility of the Company; my Lords do not propose to interfere in the selection of the parties who are to execute the work, further than to see, that its proper execution is sufficiently secured. My Lords have no doubt, that the Company will adopt the proper means of procuring contracts for the execution of the work on the best terms, and can only refer Messrs. Glass, Elliot, and Company, to the Directors of the Company."

The first of these documents proceeded from rival manufacturers, who might have been impelled by hostile feelings; but no public contradiction, or explanation had ever been offered of the facts alleged.

On the 27th of August, 1858, the Chairman of the Board of the Red Sea Telegraph Company, in a letter to the Treasury, said:—"As regards the selection of Contractors, they [the Directors] beg to state, that the choice lay between two firms, and that, in a matter of so much importance, and with so limited a number of competitors, it appeared to them, that the early and satisfactory completion of the enterprise would be most effectually promoted, by the selection of the Contractors who combined the highest reputation, with the largest experience in laying submarine cables. The reputation of Messrs. Newall and Co. stood preeminent, and they had already succeeded in laying several telegraphic lines."

Inclosed in this letter, was "A Memorandum of Agreement made and entered into between the Red Sea and India Telegraph Company, of the one part, and Robert Stirling Newall, Charles Liddell, and Lewis Dunbar Brodie Gordon, all of Abingdon Street, Westminster, trading under the firm of Newall and Co., of the other part," covenanting, that "the said Messrs. Newall and Co. shall manufacture and lay down 'the cable' from Suez to Aden, and, if the Board should require it, and announce their desire to that effect, within four weeks from the date hereof [left blank in the Blue Book], from Aden to Kurrachee, at their own risk and responsibility, and deliver 'the cable' complete, and in full working order and condition, for the sum following, viz.:—

"From Suez to Aden, for the sum of £225,000;

"From Aden to Kurrachee, for the additional sum of £246,425.

"The Board are to have the right of inspecting the cable and materials, during manufacture and while laying, by their own members, and by their officers and persons appointed by them, in such manner and at such times as they may think fit."

On the 23rd of September, 1858, Mr. J. Cosmo Melvill wrote:—

"With regard to the proposed arrangements for executing the work, Lord Stanley is not aware of the reasons which induced the Directors of the [Red Sea] Telegraph Company, to enter into a contract for the cable, without resorting to the system of competition; and he does not perceive why that principle could not have been advantageously applied in this case, or why both the firms engaged in the manufacture of the cable, which the Directors appear to have taken for their model, should not have had the opportunity of making a tender.

"With regard to the description of cable which has been fixed upon, Lord Stanley is inclined to urge, that every precaution should be taken to secure the best that can be devised for the purpose. It is well known, that grave doubts are entertained by some authorities, as to whether the Atlantic cable meets all the requirements of a submarine telegraph work, and he would suggest, therefore, the desirableness of obtaining the concurrent opinion of two, or more eminent authorities upon the subject, before making final arrangements.

"Having perused the proposed Agreement with the Contractors, the only observations with regard to its terms which I am desired to make, are, that it would be desirable to modify the first clause, so as to oblige the Contractors to keep 'the cable' in working order for one month, at least, from the date of the first message passing through it; and that Clause IV. should be made quite clear upon the power of the Telegraph Company to test, as well as inspect the cable and its component parts, in all stages of its manufacture."

This letter must be borne in mind, as it related to the important points of the contract being given without competition,—the form of the cable, referring to the "grave doubts" entertained with respect to the Atlantic cable, which, at that period, had virtually failed,—and the obligation to be imposed on the Contractor to keep 'the cable' in working order for one month at least, from the date of the first message passing through it, the original proposed period of maintenance being only ten days.

It should be observed that, up to this point, no mention was made of the testing, or of the reception of 'sections' of the cable; but 'the cable,' meaning the whole extent of the cable from Suez to Kurrachee, was, evidently, intended by the Government, and by the Red Sea Telegraph Company.

In the letter of the 28th of September, 1858, from the Chairman of the Red Sea Telegraph Company to the Treasury, after repeating the former reasons for giving the contract to Messrs. Newall and Co., it was stated:—"But it was also supported by the consideration, that the firman from the Turkish authorities, which was the basis of their operations, would lapse, unless the telegraph was established between Constantinople and Alexandria, before the end of the present year (1858); and that Messrs. Newall and Co. engaged, on receiving the Red Sea contract, to complete that telegraphic communication from their own resources, in time to save the Turkish concession."

Now it must be observed, that up to the present time (1861), no communication between Constantinople and Alexandria had ever been made; yet that was one of the chief reasons for not submitting the contract to public competition.

In that same letter it was said:—"The Board have communicated to the Contractors the desire of Lord Stanley, that the period for which they should be bound to maintain 'the cable' in working order, be extended from ten to thirty days, and they hope to be able to effect the arrangement."

In the contract with Messrs. R. S. Newall and Co., dated October 23, 1858, it was stipulated, that they "shall manufacture and lay down 'the cable' from Suez to Kurrachee, at their own risk and responsibility, and deliver over the same to the Company, complete, in full working order, and in condition to transmit ten words per minute."

In Clause V. of this contract, which stipulated for certain payments being made to the Contractors as the work proceeded, it was said: "And no part of the money is to be considered as due until the cable, 'for each section,' shall have been efficiently at work, as hereinbefore specified, for one clear calendar month," &c.

"Any surplus cable remaining, after the final completion of the contract, is to belong to the parties of the second part [the Contractors]."

These documents exhibited, prominently, the duty of an Engineer, to exercise great care in drawing up a contract, as well as to see all the provisions scrupulously carried out.

It would be observed, that whereas the tender of Messrs. Glass, Elliot and Co., was £460,000, that of Messrs. Newall and Co., was £471,425; yet the general result involved in the tender of the former firm, was evaded. It must be borne in mind also, that Messrs. Glass, Elliot and Co. had stated in their first letter to the Treasury, that they had examined the estimates, and were prepared to execute the same work for £100,000 less. This, however, was entirely overlooked by the Directors, who only said they considered the question of £10,000 was immaterial, because they had received an undertaking from Messrs. Newall and Co., to complete the cable from Constantinople to Alexandria, and thus to connect India with Europe; which, however, was not even yet accomplished. It was to be remarked, however, that no formal undertaking, on the part of Messrs. Newall and Co., to complete this communication, appeared in the official papers.

These details might appear prolix, but it was impossible, otherwise, to lay clearly before the Meeting, even an outline of the case, and still less, to give a notion of the causes which had led to that lamentable failure.

In the contract, Clause IV., it was provided, that the Board itself, or by its officers, were to have the right of inspecting and testing the cable as well as all the materials, during manufacture, and whilst being laid, but not so as to interfere with the process of manufacture. But as regarded the laying, the Meeting had been told by one of the Engineers of the Company, that they never had any responsibility, as they never were permitted to interfere in the laying of the cable.

Another condition of the contract was, that the estimates allowed 20 per cent. of extra length, in order that the cable might be laid sufficiently slack. Another clause, however, gave to the Contractors all such portions of the extra length as were not actually laid; thus actually offering a premium for laying the cable as 'taut' as possible. The obvious result was, that in consequence of the Engineers not having any authority to interfere with the mode of submerging, the cable was laid with so little slack, that failures declared themselves almost immediately; and eventually, a vessel was engaged, during one hundred and eighty-two days, in abortive attempts to repair one hundred and eighty-four miles of cable.

It was evident, that a contract had been made, which absolved all parties from responsibility. The Engineers had no power of interference, and the liability of the Contractors was restricted to thirty days. Even here, however, there was an ambiguity; the Government demanded that 'the cable,' meaning the entire cable, should be kept in perfect working order, during thirty days, at least: but in dealing with the Contractors, the Company apparently omitted to insist upon this condition, as although it was admitted, that each of the subdivisions of the cable, when laid, had conveyed messages during the minimum period, yet no messages had ever travelled throughout the line, (beyond one, or two days,) according to the evident intention and provision of the Government, and on the faith of which a guarantee had been granted. It had recently been stated, that Messrs. Newall and Co. declined to enter into the contract, if they were held to the maintenance of the entire line for thirty days. The question appeared to have been settled by a compromise between the Company and the Contractors, and the public was saddled with the payment of nearly £36,000 per annum; whilst, probably, all the work would have to be done over again, as the present cable, now lodged on the bottom of the Red Sea, was of no earthly utility, save to the zoophytes, which, no doubt, were closely attached to it.

Now as to the Rangoon cable. The Government requested the opinion of the late Mr. Robert Stephenson, upon the form of a cable to be laid between England and Gibraltar, and the suitable construction was pointed out. This recommendation was reported upon by the Engineer, who was appointed to the project. It was however imagined, that the line might be interfered with, in case of hostilities, and this cable, which was originally designed for a deep-sea line, was now ordered to be transferred to Rangoon, to be laid between that place and Singapore, a considerable portion of which route was through comparatively shallow water. The next that was heard of this unhappy cable was, that it was in a state of fermentation; whether from the hemp covering, or from the oxidation of the iron, was not stated. But its destination had been again changed, and it was now, apparently, to be transferred to the station between Malta and Alexandria, to supersede the cable for establishing a communication between Constantinople and Alexandria, which Messrs Newall and Co. had undertaken to lay, but which had not yet been completed. The statements of the Blue Books on this subject were curious, and deserved careful attention. As to the construction of the cable, it appeared to be of superior character, and it was a matter of regret, that it had not been laid in the place for which it was originally designed.

It was evident, that there were in electric telegraphy, other considerations beyond scientific knowledge and mechanical skill, and those who had to deal with the subject, must be prepared to cope with difficulties arising from other and far different causes. An instance in point, was the accident which had recently happened to a line laid between England and the Continent, for the International Telegraph Company. The cable contained four conducting wires, and whilst it was coiled, the whole acted perfectly, but when it was laid, only three of the wires were found to be capable of performing their duty. The Directors, unlike the Government, had bound the Contractors to lay a perfect cable; they refused, therefore, to receive it in that condition. The Contractors expended a large sum in ineffectual attempts to raise the cable, and to discover the cause of the failure, during a stormy season. On the return of propitious weather, they were more successful, and they then discovered, that a nail had been skilfully inserted into the cable, in such a manner as to destroy the action of one wire. A person who had been on board during the submersion of the cable, at length confessed, that he had been in the pay of other parties; that at their instigation, he had sought for employment under the Contractors, and had, under instruction, inserted the nail. As the case would very shortly be brought before a court of justice, it would be improper to enter into further particulars, but the occurrence justified the severe remarks as to 'moral causes,' that had been made during the discussion.[1]

The most important part of this question, was the necessity of taking the proper steps for insuring a satisfactory submarine telegraphic communication. Several of the deep-sea Mediterranean lines had failed from mechanical causes, some of which had been foretold, before the submersion of the cables had been attempted. This demonstrated the necessity for more careful and accurate surveys of the bottom of the ocean, to the depth of 500 fathoms, or 600 fathoms on the lines where cables were to be laid.

Although it was essential, that a proper route should be selected, it was not requisite to have the entire bottom of the sea mapped out, with the great accuracy which had sometimes been contended for, as it would involve too great an expense. Experience had shown, that the destruction from mechanical abrasion only took place within limited depths; the more elaborate survey might, therefore, be restricted to practical depths, and in shallow waters it should be minute. Within soundings, the cable should be strong, and heavy, but a smaller section might be used beyond. At all events, if that plan was adopted for the cable between England and Gibraltar, there would be little fear of damage from hostile disturbance. He suggested, that an instrument might be devised which would indicate, with sufficient accuracy, the general character of the bed of the ocean, upon a plan similar to that adopted for measuring the rise and fall of tides, the record being made by the passage of a pencil over a sheet of paper moved by clockwork.

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[1] *Vide* "Guildhall, February 20th and 21st, 1861. Before Chief Justice Erle and a special jury. Glass *v.* Boswall. Transcript of Messrs. Cocks' short-hand notes." 8vo. London: Waterlow and Sons.

Corrosion, could not be prevented, especially where the cable reposed upon sand; but, commercially, that difficulty could be met, by making a provision for renewal, at intervals, say of seven, or eight years. So serious an element in the cost of submarine cables, was their liability to corrosion, that in the cables of the Electric Telegraph Company, the depreciation arising from this cause alone, was estimated at £8,000 per annum.

A main point was the form of contract which the Government should enter into with parties offering to lay down cables. It appeared, that at present few, if any, of the submarine telegraphs were remunerative 'per se'; and with the failures of the Atlantic and the Red Sea cables as precedents, companies would scarcely be found to embark in such undertakings, without some Government assistance. Then came the question of the terms upon which the Government might safely enter into such engagements. After considering all that had been done up to the present time, as described in the Blue Books, it appeared, that the safe course would be to negociate only with such Contractors as were known to be responsible and trustworthy, to pay them a sum not exceeding the actual cost of the cable, and then to covenant to pay a liberal per centage for the use of the cable, for the period during which it actually remained in working order. The amount paid for effective service was a minor consideration, when compared with the arrangement, by which the country had been saddled with an annual payment of nearly £36,000, without the chance of deriving any practical benefit.

He believed, that the free discussions of the subject in this Institution, would materially aid the progress of submarine telegraphy, and would, eventually, enable Engineers to proceed with the same certainty as to the result, which was attached to the other branches of Civil Engineering. He also hoped, that the expression of opinion which had been elicited, would lead, elsewhere, to a more practical consideration of the question, than it had, hitherto, received.

December 4 and 11, 1860.

GEORGE PARKER BIDDER, President,
in the Chair.

The discussion upon the Paper, No. 1,030, "On the Maintenance and Durability of Submarine Cables in Shallow Waters," by Mr. W. H. Preece, was continued throughout these evenings, to the exclusion of any other subject.

At the Meeting of December 4, the following Candidates were balloted for and duly elected:—ALEXANDER BEAZLEY, HENRY GILL, WILLIAM GEORGE OWEN, JOHN HENRY PARK, AUGUSTE PERDONNET, and JOHN HARRISON STANTON, as Members; HIRAM CRAVEN COULTHARD, THOMAS GREENWOOD, EDWARD DAMES HAMILL, THOMAS WILLIAM KINDER, JOHN HORATIO LLOYD, Captain JAMES PUCKLE, FRASER SELBY, and GEORGE LOUIS VAUGHAN, as Associates.

ANNUAL GENERAL MEETING.

December 18, 1860.

GEORGE PARKER BIDDER, President,
in the Chair.

MESSRS. T. M. JOHNSON, J. P. KENNEDY, and J. THOMSON, were requested to act as Scrutineers of the Ballot, for the election of the President, Vice-Presidents, and other Members and Associates of Council.

The list of the attendances of the Members of Council for the past year was read, and the Ballot was commenced; the balloting-papers being sent for examination, at intervals of fifteen minutes, in order to expedite the labours of the Scrutineers.

The Annual Report of the Council, on the proceedings of the Institution during the past year, was read.

Resolved,—That the Report of the Council be received and approved; and that it be referred to the Council, to be printed and circulated with the Minutes of Proceedings, in the usual manner.

Resolved,—That the thanks of the Institution are due, and are presented to Messrs. Maudslay and Kingsbury, for the readiness with which they undertook the office of Auditors of Accounts, and for the clear statement they have laid before the Meeting; and that Messrs. Kingsbury and Stileman be requested to undertake the office of Auditors for the ensuing year.

The Telford and Watt Medals, and the Council and Manby Premiums, which had been awarded, were presented.

Resolved,—That the thanks of the Institution are due and are presented to the Vice-Presidents, and other Members of the Council, for their co-operation with the President, their constant attendance at the Meetings, and their zeal on behalf of the Institution.

Mr. Hawkshaw, V.P., and Mr. Hawksley, returned thanks.

Resolved unanimously,—That the cordial thanks of the Meeting be given to Mr. G. P. Bidder, President, for his strenuous efforts in the interests of the Institution, for his extraordinary attention to the duties of his office, and for the urbanity he has at all times displayed in the Chair.

Mr. Bidder returned thanks.

Resolved unanimously,—That the cordial thanks of the Meeting be given to Mr. Charles Manby, the Honorary Secretary, and to Mr. James Forrest, the Secretary, for their constant zeal and devotion to the interests of the Institution, the ability displayed by them in the execution of their duties, and their attention to the individual wishes of the Members.

Mr. Manby and Mr. Forrest returned thanks.

The Ballot having been open more than an hour, the Scrutineers, after examining the papers, announced that the following gentlemen were duly elected to fill the several offices in the Council for the ensuing year:—

President.

GEORGE PARKER BIDDER.

Vice-Presidents.

John Fowler.
Charles H. Gregory.
John Hawkshaw, F.R.S.
John R. McClean.

OTHER MEMBERS OF COUNCIL.

Members.

Sir W. G. Armstrong, C.B., F.R.S.
Joseph Cubitt.
John E. Errington.
Thomas E. Harrison.
Thomas Hawksley.
George W. Hemans.
John Murray.
J. Scott Russell, F.R.S.
George Robert Stephenson.
Joseph Whitworth, F.R.S.

Associates.

Capt. Douglas Galton, R.E., F.R.S.
Henry Arthur Hunt.

Resolved,—That the thanks of the Meeting be given to Messrs. Johnson, Kennedy, and Thomson, the Scrutineers, for the promptitude and efficiency with which they have performed the duties of their office, and that the ballot-papers be destroyed.

ANNUAL REPORT.

Session 1860-61.

In presenting an account of the proceedings during the last twelve months, the Council have not imposed upon them the task of explaining, as in the early days of the establishment of the Institution, what objects are proposed to be served by it, nor the manner in which it is thought those objects may be best attained. These are now familiar to all the Members, and generally, to the scientific world. Again, in former years, frequent reference had to be made to the modifications and to the changes in the mode of conducting the business, and in the Bye-Laws, as they were severally shown to be capable of improvement. More recently, and particularly during the last Session, the proceedings have not been marked by any features of this nature, though still characterised by events of great interest. The principal duty of the Council has been to carry out, and to persevere in, the practice and the regulations established during previous years, which have been found to contribute so much to the steady growth and increasing importance of the Institution.

On this occasion, a short account will be given of the state of engineering in a few distant countries, and particularly, in some of the British Colonies; these undertakings being, probably, not generally so well known, and because attention has previously been chiefly directed to engineering progress in the United Kingdom, and on the Continent of Europe.

At the Cape of Good Hope, a railway, the first undertaking of the kind in that colony, has been commenced, which will run from Cape Town, through Stellenbosch, to the Paarl and Wellington, a distance of about 58 miles. The works on the Cape Town end of the line are light, the route being over sand flats. At the Wellington end, the country is hilly, and the character of the works is heavier in proportion. There are about twenty iron bridges, the largest of which is over the Berg River, in three spans of 170 feet each. There will be eight stations, including the two termini. The first section of the line will, it is expected, be opened shortly.

At Cape Town, arrangements will be made to connect the railway with the harbour works now being carried out, under an Act passed by the Colonial Legislature, in 1858. These works comprise a pier, or breakwater, running from the western shore of Table Bay, in a north-easterly direction, for a length of 3,250 feet, or 3,000 feet beyond the line of 2-fathoms depth of water; and they will provide refuge accommodation, and commercial facilities, at an estimated cost of £400,000. In order to procure materials for the breakwater, which will be formed by a rough rubble mound, a basin is to be excavated, having an area of 10½ acres, with a depth of 20 feet at low water of spring tides; and there will be about 4,100 lineal feet of quays. There will also be an outer basin with an area of about 4¼ acres, which, it is thought, will be available for the trade, in about two years and a half. The rock on the site of the inner basin has been thrown up so as to approach, very nearly, a vertical line; thus no side walls will be necessary. The sides of the basin will be lined with fender piles, and be provided with all the usual facilities for conducting the trade of the port. It is proposed, ultimately, to form two dry docks, or ship lifts, in connection with the basin; but these are not provided for in the estimate already named.

The principal engineering works in progress in Australia, are Roads, Telegraphs, and Railways. In New South Wales, the roads are described as being in a bad condition. They appear to have been constructed, originally, by convict labour, and no proper provision seems to have been made for their maintenance. Even the sums now voted by Parliament are not considered sufficient to thoroughly repair and maintain them. In Victoria, the roads are stated to be quite equal to English turnpike roads,[1] whilst the few which exist in South Australia are also said to be very good. Telegraphic communication was established between the capitals of the three colonies in October, 1858; and Tasmania, or Van Diemen's Land, has been connected with the mainland, by means of a submarine cable, which is now unfortunately damaged, between King's Island and the Hummocks.[2] The telegraph wires, which are carried overground, extend from Adelaide to Melbourne, thence to Sydney, and from Sydney to the northern districts; and they are intended, ultimately, to be advanced to Brisbane, the capital of Queensland, (late Moreton Bay). There is likewise a line of telegraph from Sydney westwards to Bathurst; and, in fact, the wires may be seen wherever there are towns. There are now in operation 1,000 miles in Victoria, about 1,000 miles in New South Wales, and nearly 500 miles in South Australia. They have proved a very remunerative investment, paying from 16 to 17 per cent. in New South Wales, and upwards of 7 per cent. in Victoria. In connection with the telegraph office in New South Wales, a money-order system has been established for sums up to Twenty Pounds.

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[1] It may be noted, that in New South Wales and in Victoria, there is a similar difference in practice in regard to the railways. In New South Wales, the American plan of making cheap lines, with timber bridges and viaducts, is followed; whilst in Victoria, the opposite course is pursued, all the works being executed in the most solid, substantial, and even costly style, as English railways have been constructed.

[2] This cable was laid in short lengths from island to island in Bass's Straits, and is believed to have been brought in contact with various reefs, on which it has fretted, and been worn away. Between King's Island and Cape Otway, Victoria, as well as along the coast from Circular Head to Georgetown, the cable has remained in good working order throughout; the bed on which it rested being, in these cases, composed of sand.

The railways, with the exception of two, or three short lines near Melbourne, all belong to the Government, and have been carried out by means of loans; the only private undertaking of any magnitude, the Geelong and Melbourne Railway, a single line, having lately been purchased by the Government for about £750,000, at par, or nearly £19,000 per mile. This plan has been adopted, to prevent any financial difficulty interposing to delay the completion of works, considered to be so necessary for the prosperity of the three colonies. In South Australia, a proposal has recently been made to inaugurate a fresh policy. Two new railways are projected; a short suburban line, to which it is proposed to give a limited guarantee, and a more important line, 100 miles in length, from the head of Spencer's Gulf, in a north-easterly direction, to a district rich in copper ore, towards which a dotation of land is offered. Unfortunately, a uniform gauge has not been adopted, as it should have been, in all the colonies; for, whilst in Victoria and in South Australia, the rails are laid to a gauge of 5 feet 3 inches, in New South Wales the gauge is 4 feet 8½ inches. This is likely to cause serious inconvenience in the future, when the main trunk lines to connect the capitals of the respective colonies, are completed.

The railways in progress in New South Wales, (with its population of 300,000, of which 80,000 belong to Sydney alone,) are: the Great Southern; the Great Western; and, the Great Northern.

The Great Southern, or main trunk line from Sydney, ultimately intended to join the Victorian system of railways at the River Murray, has been opened as far as Campbelltown, a distance of 34 miles. The works are light on this section, with the exception of one viaduct of stone and brick, crossing a valley about 5 miles from Sydney. The ruling gradient is 1 in 70. Up to Parramatta, 13½ miles, there are two lines of way; and the cost of this division, including rolling stock and machinery, and the workshops at the terminus, has amounted to about £40,000 a mile. Beyond this point there is only a single line, and the cost from Parramatta to Liverpool, 8½ miles, has been £14,200 per mile, and from Liverpool to Campbelltown, 12 miles, £7,600 per mile. It is expected, that a further length of 20 miles, from Campbelltown to Picton, will be completed in a few months. On this division there will be a large bridge over the Menangle River, the water in which has been known to rise 50 feet in twenty-four hours. The country traversed is said to resemble the district of Craven, in Yorkshire. The works are, accordingly, heavy, and numerous large culverts are necessary. The earthwork consists of about two-thirds of hard schist, and one-third of ordinary material. Trial surveys have been made and estimates prepared of the cost of extending this line to Goulburn; from which it appears, that the natural difficulties are such as will necessitate an expenditure greatly in excess of that hitherto incurred.

The Great Western Line, which starts from the Great Southern Line, 1½ mile west of Parramatta, was opened as far as Blacktown, on the Windsor road, a distance of 8 miles, in August, 1860. The works are light, there being only a few timber viaducts, and the cost has averaged about £10,500 per mile of single line. From Blacktown to Penrith, a length of only 12 miles, the works of importance are five large timber viaducts, for crossing rivulets liable to excessive floods. This line is, at present, proposed to be carried to Bathurst, and extensive surveys and explorations have been made of the country between the Hawkesbury and that place, including the valley of the Grose, in order to discover a practicable route, by which to pass the range of the Blue Mountains. It is believed, that it will be possible to obtain a line with a gradient of 1 in 50, though the works will be much more costly than any yet made. The district to be traversed, is rich in all kinds of minerals, and the country beyond Bathurst is very fertile.

The Great Northern Railway starts from Newcastle, about 60 miles north of Sydney, between which places there is steam-ship communication, daily. The line was opened, two years ago, to East Maitland, and subsequently to West Maitland, a total distance of 20 miles; and in August, 1860, from West Maitland to Lochinvar, a further length of 8 miles. On the section from Lochinvar to Singleton, a distance of 23 miles, the works will be finished about the middle of 1861. The expenditure has amounted to nearly £15,000 per mile of single line. The country is under survey beyond Singleton, as far as Muswellbrook, a distance of 70 miles, to which point it is thought this line will be advanced. The district abounds in minerals, and particularly in coal, from which all the Australian colonies, as well as India and China, may be supplied. Both the Wallsend and Minmi collieries have railways to the main line, and several other branch mineral railways are in contemplation from the different collieries. Already there are timber staiths on the quay at Newcastle, to facilitate the tipping of coal from the waggons into the ships.

The average rate of wages in New South Wales is, for ordinary labour, 8*s*.6*d*.; masons and blacksmiths, 14*s*. each; and carpenters, 13*s*. per day of ten hours.

In the thriving colony of Victoria, with its immense commerce in gold and its large field for 'squatting;'—where there is a population of 500,000, there being in Melbourne alone about 150,000, —the railways now open are, the Geelong and Melbourne, a single line, 40 miles long, passing through a level country, in connection with which there are extensive piers and wharves at Williamstown, the port of Melbourne. Also the Suburban Railways, which have been constructed by private companies, in whose hands they still remain. These are:—the Melbourne and St. Kilda; the St. Kilda and Brighton; the Melbourne to Richmond, Hawthorne, and Brighton; and the Melbourne and Hobson's Bay, a double line, 3 miles in length. At Hobson's Bay there is a pier, where large clipper ships are unloaded, by the aid of portable steam engines.

The great lines to the interior, now in course of construction by the Government, are:—the Geelong and Ballaarat, a length of 53 miles, of which no part is yet open; and the Melbourne and Mount Alexander, to Castlemaine, Sandhurst, and Ecucha, on the River Murray, a length of 152 miles. The main line has been opened to Sunbury, a distance of 22 miles, and also the branch to Williamstown. The portion of the line from Sunbury to Woodend, a length of 28 miles, is expected to be finished early in 1861. The estimated cost of these two lines, both of which will consist of a double way, is £7,000,000, or upwards of £34,000 per mile, of which £3,000,000 sterling have been already raised and expended.

With respect to the general character of the country through which these lines run, Mr. G. C. Darbyshire, the late Engineer-in-chief, writes:—"From the coast to the dividing range the land rises regularly, with the exception of one sudden step of 300 feet, to a height of about 2,000 feet, in 40 miles. The surface is unbroken, except by occasional chasms 100 feet to 500 feet in depth, and from 660 feet to 3,300 feet in width. Through these ravines, the immense quantity of water which falls on the higher ranges is discharged, with impetuous velocity. There is a total absence of those great leading valleys which are found in England."

On the Geelong and Ballaarat Line, the gradients are generally favourable, although there is one incline of 1 in 68 for nearly 3 miles, and another of 1 in 63 for upwards of 3 miles. The contract time for completing this railway throughout, will expire on the 31st of July, 1861. The greater portion of the earthwork is already completed. The viaduct over the valley of the Moorabool, will be 1,300 feet in length, and upwards of 100 feet in height. There will be ten openings of 130 feet each, spanned by Warren girders.

On the Melbourne and Mount Alexander Line, the average gradient in the first 25 miles, is 1 in 130; but gradients of 1 in 78, 1 in 67, and 1 in 61, occur in lengths not exceeding ½ a mile. In the next 25 miles the summit level is attained, to reach which, the average gradient is about 1 in 100, with inclines varying from 1 in 52 to 1 in 56 for a distance of about 5½ miles. At the summit the line is nearly level, but before reaching Castlemaine it descends at the rate of 1 in 50 and 1 in 60 for 4 miles. Between Castlemaine and Sandhurst there are about 6 miles, of from 1 in 56 to 1 in 50, the average gradient being steeper than 1 in 80. From Sandhurst to the River Murray, the line is nearly level, with a few gradients, the steepest of which is 1 in 100. Of the three viaducts immediately beyond Sunbury, two are nearly completed, and the third, that over Jackson's Creek, is finished as regards the stonework. The wrought-iron plate girders are now being elevated to their position. Jackson's Creek and the Yarrowee River are each crossed by bridges 262 feet long, having three openings, the centre one being a span of 84 feet 6 inches. The cutting north of Sunbury, containing about 230,000 cubic yards, is finished, except the trimming and clearing up. Of the earthworks on the entire contract, upwards of 2,500,000 cubic yards of earth and rock have been removed and placed in the embankments. The greater portion of the culverts throughout the line, are finished. The Riddle's Creek Viaduct, consisting of a stone arch, 60 feet in span, and 50 feet high, and the Coliban Viaduct, a stone structure of five segmental arches, each 60 feet in span, and 80 feet in height, have been completed. The Taradale Viaduct will be 650 feet in length and 120 feet in height, containing five spans of 120 feet each, which will be composed of wrought-iron plate girders, resting on bluestone masonry piers.

The larger rivers, creeks, and ravines on both these lines, have been crossed, generally, by viaducts constructed with abutments and piers of bluestone masonry and wrought-iron superstructures.

The permanent way is of the most substantial character, consisting of a double-headed rail, weighing 80 lbs. per yard, fished at the joints, and fixed by keys in the ordinary mode, in chairs weighing 34 lbs. each, which are laid on sleepers of native timber. The materials for the permanent way, (excepting the sleepers,) the iron bridges, locomotives, rolling stock, machinery, tools, &c., have been obtained in England. Workshops are now being erected at Melbourne, which will be fitted for the repairs of marine engines, as well as of locomotives.

The rate of wages is from 10 to 20 per cent. higher in Victoria, than in New South Wales; ordinary labour being 9*s*., masons and blacksmiths 16*s*. each, carpenters 14*s*., and mechanics 18*s*., per day of eight hours.

In South Australia a double line of railway, from Port Adelaide to Adelaide, a distance of 3½ miles, has been open for the last three, or four years; and a single line from thence to Gawler, a length of 29 miles, for about two years and a half. From Gawler to Kapunda, where copper ore has been found in large quantities, a further length of 16 miles, the line was opened this year. It is proposed to extend this line northwards; and a railway is also in contemplation to run from Adelaide along the sea coast.

The oldest railway in Canada, a short line called the La Prairie and St. John, was opened for traffic in July, 1836. From that period until the year 1849, little progress was made in the extension of railways. At the commencement of 1857, there were 1,402 miles of line in operation; at the present time, the mileage is 1,859, and the number of railways fifteen, all of which, with the exception of the Montreal and Champlain Railway, have been constructed between the years 1852 and 1860.

The lines at present opened for public traffic are the following:—

		Miles.
1.	Grand Trunk Railway (main line and branches)	870
2.	Great Western (do.)	345
3.	Buffalo and Lake Huron	160
4.	Toronto and Northern	95
5.	Welland	25
6.	Montreal and Champlain	81
7.	Port Hope and Lindsay	43
8.	London and Port Stanley	24
9.	Erie and Ontario	17
10.	Cobourg and Peterborough	28
11.	Prescott and Ottawa	54
12.	Brockville and Ottawa	47
13.	Grenville and Carillon	13
14.	St. Lawrence and Industrie	12
15.	Stanstead, Shefford, and Chambley	45
	Total	1,859

The three principal lines are the Grand Trunk, the Great Western, and the Buffalo and Lake Huron. They run, longitudinally, through separate divisions of Canada, and were constructed with a view to secure a share of the large traffic, in passengers, goods, and agricultural produce, which finds its way from the Western States to the Atlantic seaboard, and vice versâ. The

Buffalo and Lake Huron Line communicates with New York viâ Buffalo; the Great Western Line is also in connection with New York, viâ the New York Central Railway; and the Grand Trunk Railway extends throughout the whole of the province, from north-east to south-west, and has its Atlantic outlets at Portland and Quebec. The Welland Railway, 25 miles long, was constructed two years ago, mainly for the transport of grain in bulk, and of heavy goods, in opposition to the Welland Canal, which has to overcome an ascent of upwards of 300 feet of lockage, between lakes Ontario and Erie. All the other lines depend chiefly upon local traffic. The Canadian railways have nearly all a uniform gauge of 5 feet 6 inches, and they are all single lines. On the Buffalo and Lake Huron, the Great Western, and the Grand Trunk Railways, the running of the trains is governed by means of the telegraph; and in 1856, the Great Western Company worked a traffic of upwards of £60 a mile per week, on a single line of rails. The average cost per mile of the main lines, has been about £15,000, inclusive of rolling stock and other expenses. The cost of the branches has ranged from £6,000 to £10,000 a mile. With the exception of the land, and the timber for the buildings, bridges, and sleepers, everything required for railway construction is more expensive in Canada than in England. All the rails were imported from this country, and they cost, when delivered in Canada, for freight, ocean insurance, and duty, 40 per cent. more than in England, or Wales. The rails, on the main lines, weigh 65 lbs., and on the branches, from 55 lbs. to 60 lbs. per yard. The bridges are generally of timber, which it is thought cheaper to renew every ten years, than to build at first in stone, or iron. On the Grand Trunk Railway, the bridges consist chiefly of tubular iron girders, and on the Great Western main line, there are also some wrought-iron bridges, resting on masonry piers and abutments, though the majority are of wood. The ruling gradient adopted on the Grand Trunk and on the Great Western Railways is 1 in 100. The locomotive engines are all built for the consumption of wood fuel, although coal, which costs from 16*s.* to 20*s.* per ton, has lately been used with advantage in point of cost.

The capital embarked in Canadian railways amounts, at present, to about £26,000,000 sterling, of which £4,161,150 may be considered as the contribution of the Province of Canada, inasmuch as the interest on this amount, £249,669, is an annual charge upon its revenue.

The only other engineering works constructed in Canada during the last few years, have been the deepening and improvement of the River St. Lawrence, between Montreal and Quebec; the erection of lighthouses in the Gulf of St. Lawrence; and works for the supply of water to Quebec, Montreal, and Hamilton.

In these cases the water is raised, by pumping, from the River St. Charles, the River St. Lawrence, and Lake Ontario, respectively.

During the past three, or four years, there has been great stagnation in the extension of railways in the Northern and Western States of America. In Michigan, the Grand Trunk Railway Company, (of Canada,) has constructed 55 miles, in order to connect the line with Chicago; and the Great Western Railway Company, (of Canada,) has contributed largely towards the completion of the Detroit and Milwaukee Railway, 186 miles in length, which was opened throughout, in September, 1858. This line gives the Great Western Company the shortest route to Milwaukee, on the west coast of Lake Michigan. The other American railways in progress, at present, in the North Western States, are westward of Chicago, and have all the common object in view, of opening up new territories west of the Mississippi and the Missouri Rivers. They are being constructed in the cheapest possible manner, through flat prairie lands, at a cost of about £4,000 to £5,000 per mile. The rails, which have to be imported from England, and conveyed inland 1,500 miles, are frequently the most expensive part of the line.

In Russia, the St. Petersburg and Warsaw Railway was commenced, as a Government undertaking, about the year 1851. A large portion of the earthwork had been executed, and a few miles opened before the War, when the works were nearly suspended. In 1856, this line was ceded, with others, to the Grand Russian Railway Company, (in conjunction with the Société du Crédit Mobilier, of Paris,) by whom the works are now being prosecuted. The length of the line is 1,000 versts, or about 670 miles, one-half of which is completed, though many of the works are merely temporary. A branch to connect this line with the Berlin-Königsberg Railway is being vigorously pushed forward, and the portion to the Prussian frontier is already opened for traffic.

The Riga-Dünaberg Railway, 140 miles long, running from Riga towards the producing districts, and, by its junction at Dünaberg with the Berlin and Warsaw Railways, connecting Riga with the network of European railways, is rapidly approaching completion. The works are principally conducted by English Engineers, and on this account, attract considerable attention in Russia. No temporary works are permitted on this line, and the earthworks and permanent masonry were almost all completed before the close of the last season.

The Moscow and Nijni Novgorod Line, which will connect the western ports with the extreme European east of this vast empire, by means of those important thoroughfares for goods, the Rivers

Kama and Volga, is making rapid progress, in the hands of the Grand Russian Railway Company, and one-half of this line is expected to be ready for traffic, during the next summer.

Surveys have been made by the Government for lines to cross the Caucasus,—by the Grand Railway Company, between Moscow and the Crimea,—and by parties locally interested, between Odessa and a point of junction with the last-named trunk line. Some works have been commenced, but little progress has been made; nor is it considered likely, that much more will be undertaken by the Grand Company, until the Nijni and the Warsaw Lines are open, or until the present monetary pressure is relieved.

The greatly extended use of iron in the present day, the many important purposes it serves, and the changes that have taken place in its manufacture, especially within the present century, seem to invite a short notice of iron-making processes. In India, in Persia, and even in some parts of Sweden, the primitive methods of working, in use in this country at the earliest periods, are still practised. The first great improvement in the production of iron, dates from the year 1713, when Dud Dudley, of Dudley, introduced the smelting of iron with coal, or coke, instead of charcoal, and with a heavier pressure of blast, than had been previously employed. After Dudley's death, this invention lay dormant until it was revived by Darby, of Coalbrookdale; but no great advance was made, before it received the assistance of the steam engine. The annual 'make' of a blast furnace in the year 1750, was only about 300 tons; whilst now, it ranges from 5,000 to 10,000 tons, and in a few cases, it amounts even to 15,000 tons per annum. The next great step was the introduction, by Neilson, of the hot blast. This led to economy in the manufacture, as well as an increase in the 'make,' and rendered available many classes of ores, such as the black band, which were not previously worked. Several minor improvements followed; including an increase in the diameter of the boxes of the furnace, greater pressure of the blast, and more recently, larger tops, or throats to the furnaces, the calcining of the ore, or ironstone, as well as the limestone, and, in certain districts, the manufacture of heavier coke, by mixing a small quantity of highly bituminous coal with the non-coking coal of certain localities. The last step has been the use of a greatly increased temperature of blast, which, as far as may be judged from the limited experience already obtained, bids fair to result in an increased 'make,' and a reduced consumption of coke in the blast furnace.

In reference to wrought iron, one of the earliest improvements was the use of the puddling furnace. Various machines have been tried, from time to time, for compressing the blooms of wrought iron, when taken from the puddling furnace, but these are now surpassed by the forge hammer, or a heavy steam hammer with a good fall, so far as the perfection of work is concerned.

In some establishments, homogeneous iron and charcoal iron have been made, and large forgings, weighing many tons each, for paddle-wheel and screw shafts, have been produced. The plan of reversing the rolls, first introduced to facilitate the process of rolling the links for suspension bridges, with the eyes, or enlargements at the ends solid, or in one piece with the link, has been considerably extended, in the rolling of large plates, bars, &c.; and occasionally, a second pair of rolls is placed close to the first, and running continuously in the opposite direction, the iron may be rolled either in coming forward, or in going back. Plates 1¼ inch thick, by 3 feet wide, and 20 feet long, and others 4½ inches thick, by 3 feet wide and 15 feet long, have been rolled, as well as bars up to 72 feet in length, for the construction of the spiral barrels of wrought-iron ordnance.

Most of the improvements in the manufacture of steel have been introduced within the last half century. Cast-steel bells, weighing 53 cwt. each, have been made in this country; and castings of steel, weighing 100 cwt., have been produced in Austria. Large plates and very heavy bars, of the section of angle and T iron, for steamers of light draught, and for boilers, have also been made of puddled steel, produced direct from cast iron. It may be mentioned, that steel wire, when hardened to about a deep-blue temper, before drawing it down into small wire, so that the whole section is of uniform hardness, has been found capable of carrying 130 tons per square inch.

This résumé would be incomplete, if no reference was made to the process of forcibly blowing air beneath the surface of a 'pot' of melted cast iron, so as to produce a very high temperature, by the vivid combustion of the carbon and a portion of the iron, thus decarbonising the iron in a direct manner, for the production of wrought iron, or steel. Nor must the manufacture of comparatively cheap steel be omitted, for it is a feature of the present time, fraught with important results. More than one process has been used, successfully, in the production of this material, which has been found, by recent experiments, to possess nearly double the strength of ordinary iron, accompanied by other properties, which render it valuable in its application to machinery, and to a variety of purposes connected with the arts. The demand for a better description of rails, tyre bars, points and crossings, and other articles used on railways, is also exerting considerable influence on the trade.

Not only have improvements been made in the manufacture of iron, from known mineral deposits, but new descriptions of ores, in this country and India, as well as from the colonies of Nova Scotia and New Zealand, have been brought into notice. From these ores, iron of a quality ranking with the best home and foreign 'marks,' has been successfully produced.

With regard to the application of iron, a new era commenced with the construction of the Conway and the Britannia Bridges; as the elaborate experiments made prior to their construction, tended to prove, that previously-received theories were in several respects erroneous. Again, the building erected for the Great Exhibition in 1851, from its lightness and security, called attention to the hitherto undeveloped capabilities of the combined use of cast and wrought iron for such purposes.

The improvements in the artillery and projectiles of the present day, which have resulted from the efforts of Civil Engineers, are calculated to lead to important changes in modern warfare. Simultaneously with the rapid advance in the destructiveness of weapons of offence in attack, there is a necessity for a corresponding alteration in the means of resistance. The entire reconstruction of artillery implies also, the entire reconstruction of the Royal Navy. These subjects have led to elaborate researches and experiments, for the purpose of ascertaining the best qualities of metal to resist the enormous strains and concussions which have to be encountered, and the best dispositions in which to employ them. These may be considered to be within the province of the Civil Engineer, although their subsequent use, in the business of war, must necessarily fall within the department of the Military Officer. Iron-coated ships had, for some years, been regarded as a probable coming necessity; but it was not until about the end of the year 1858, that the Admiralty, for the first time, seriously considered the subject, when certain conditions were framed, on which six shipbuilders were asked to send in tenders and designs. After receiving these, the Admiralty produced certain designs, on which the 'Warrior,' and the 'Black Prince,' are now being constructed. The problem is one of great difficulty. An enormous mass of armour has to be added to the weight hitherto carried in a ship of given armament. At the same time, greater speed is demanded, and that involves an increased weight of engines and a larger supply of fuel. Then again, the weight is top-weight and wing-weight, and all this must be carried on fine lines, for speed. To reconcile these conditions with the practical points in a war vessel, to give such a ship good sea-going qualities, and to make her well suited for a voyage, and for the probable conditions that would attach to a European war, is a problem which may well employ the professional skill of Naval Architects, and of every Member of the Institution.

The principal Papers read during the Session were:—"On the Process of Raising and Hanging the Bells, in the Clock Tower, at the New Palace, Westminster," by Jabez James, (Assoc. Inst. C.E.); "On the Government Waterworks, in Trafalgar Square," by C. E. Amos, (M. Inst. C.E.); "On Arterial Drainage and Outfalls," by R. B. Grantham, (M. Inst. C.E.); "On the Construction and Enlargement of the Lindal Tunnel, on the Furness Railway," by F. C. Stileman, (M. Inst. C.E); "On the Means of Communication in the Empire of Brazil; chiefly in reference to the Works of the Mangaratiba Serra Road, and to those of the Mauá, the first Brazilian Railway," by E. B. Webb, (M. Inst. C.E.); "Description of the Netherton Tunnel Branch of the Birmingham Canal," by J. R. Walker, (M. Inst. C.E.); "On the Construction of Artillery, and other Vessels, to resist great internal pressure," by J. A. Longridge, (M. Inst. C.E.); "On Combined Steam," by the Hon. John Wethered, U. S.; "On the Efficiency of various kinds of Railway Breaks, with Experimental Researches on their Retarding Powers," by W. Fairbairn, (M. Inst. C.E.); "Account of the Works, recently constructed, upon the River Severn, at the Upper Lode, near Tewkesbury," by E. L. Williams, (M. Inst. C.E.); "On Coal-Burning and Feedwater Heating, in Locomotive Engines," by D. K. Clark, (Assoc. Inst. C.E.); "On Indian Railways, with a Description of the Great Indian Peninsula Railway," by J. J. Berkley, (M. Inst. C.E.); "On the Method of Computing the Strains and Deflections of Continuous Beams, under various Conditions of Load," by J. M. Heppel, (M. Inst. C.E.); and "On Breakwaters, Part II.," by M. Scott, (M. Inst. C.E.).

The following Telford and Watt Medals, and Council and Manby Premiums of Books, have been awarded to the Authors of some of these communications:—

1. A Telford Medal, and a Council Premium of Books, to James John Berkley, (M. Inst. C.E.,) for his Paper, "On Indian Railways, with a Description of the Great Indian Peninsula Railway."
2. A Telford Medal, to Richard Boxall Grantham, (M. Inst. C.E.,) for his Paper, "On Arterial Drainage and Outfalls."
3. A Watt Medal, and the Manby Premium, in Books, to James Atkinson Longridge, (M. Inst. C.E.,) for his Paper, "On the Construction of Artillery, and other Vessels, to resist great internal pressure."
4. A Council Premium of Books, to Edward Leader Williams, (M. Inst. C.E.,) for his "Account of the Works, recently constructed, upon the River Severn, at the Upper Lode, near Tewkesbury."
5. A Council Premium of Books, to Edward Brainerd Webb,

(M. Inst. C.E.,) for his Paper, "On the Means of Communication in the Empire of Brazil; chiefly in reference to the Works of the Mangaratiba Serra Road, and to those of the Mauá, the first Brazilian Railway."

6. A Council Premium of Books, to Francis Croughton Stileman, (M. Inst. C.E.,) for his Paper, "On the Construction and Enlargement of the Lindal Tunnel, on the Furness Railway."
7. A Council Premium of Books, to James Ralph Walker, (M. Inst. C.E.,) for his "Description of the Netherton Tunnel Branch of the Birmingham Canal."
8. A Council Premium of Books, to Daniel Kinnear Clark, (Assoc. Inst. C.E.,) for his Paper, "On Coal-Burning and Feedwater Heating, in Locomotive Engines."

In Mr. Berkley's Paper "On Indian Railways, with a Description of the Great Indian Peninsula Railway," it was stated, that the railways now being constructed, would be the first introduction of proper facilities of communication, and that, therefore, they could not fail to aid materially in the development of the commerce of India. After explaining what had been done towards the establishment of a general system of railways, the Author proceeded to a more particular description of the line and works of the Great Indian Peninsula Railway, of which he was the Chief Engineer in India, reserving for future communications the details of the principal works of construction, especially of those connected with the ascent of the Bhore and the Thul Ghauts. The geological nature of the country, and its physical geography were then described; and a statement was given of the materials procurable for railway purposes, of the character of native labour and its cost as compared with similar labour in England, as well as of the prices of different kinds of work. In the discussion, the progress which had been made on the other main lines was referred to, and the relative advantages of carrying out the works by the system of large contracts, or by the Company's own Engineers, were commented on. It was shown, that the introduction of railways had already awakened a spirit of enterprise which did not previously exist, and had given remunerative employment to a large portion of the population.

Mr. Grantham, in his Paper, "On Arterial Drainage and Outfalls," called attention to some of the evils arising from the want of a combined system of operation, and to the impediments which existed to prevent the adoption of arterial drainage. He then reviewed the chief undertakings of this class, including the arterial drainage and outfall works in Ireland, and in the fen districts of Lincolnshire, called the Bedford Level, and he alluded to the manner in which the rivers in India and in Northern Italy had been treated. The drainage of Hainault Forest was then described in detail, and its effect in improving the health and condition of the resident population, was shown. In the discussion it was remarked, that in attempting to remedy the present evils, care must be taken, that greater ones were not incurred, and that individual obstinacy should not be made a subject for special legislation. It was further contended, that any general measure for the control of arterial drains and outfalls would, in this country, where the rights of property were so complicated, be so injurious by its interference with those rights, that the propriety of such an act was more than doubtful.

The mode of constructing a gun of sufficient strength to enable the artillerist to obtain the full effect of the explosive compound used in it, formed the subject of an inquiry undertaken by Mr. J. A. Longridge, the results of which were communicated to the Institution in the Paper, "On the Construction of Artillery, and other Vessels, to resist great internal pressure." It was argued, that the proper principle on which to proceed, was to build up a gun in successive layers, with increasing initial tension. This system had been partially adopted by Captain Blakely and Mr. Mallet, (M. Inst. C.E.,) both of whom sought to apply it by means of hoops. But Mr. Longridge considered, that wire afforded greater facility of construction, and that the coils might be laid on with the utmost accuracy as regarded tension, and with the same ease and regularity as thread was wound on to a bobbin. The intense interest which the discussion upon this Paper excited will long be remembered, and although protracted over six evenings, it was sustained to the last. As this Paper and the discussion upon it have been printed and circulated, no attempt will be made to give a précis of the remarks which were offered, embracing, as they did, such a variety of topics. It will be sufficient to state, that the two great competitors, in the matter of artillery, Sir William Armstrong and Mr. Whitworth, both Members of the Council, each exhibited a 12-pounder gun on his system, described its mode of manufacture, and explained its working. It should also be mentioned, that Sir William Armstrong's gun had never been exhibited before, and that the first instance of all its details being made public, was within these walls. The Council conceive, that both these gentlemen are entitled to the best thanks of the Members. The high opinion universally entertained of Mr. Longridge's Paper, is marked by the award of a Watt Medal and the Manby Premium of Books; for although the subject itself was undoubtedly interesting, yet the Council are well aware, that the able manner in which it was introduced, contributed, in no small degree, to lead to so satisfactory and useful a discussion.

The "Account of the Works, recently constructed, upon the

River Severn, at the Upper Lode, near Tewkesbury," by Mr. E. L. Williams, was a supplement to former communications, descriptive of the works for the improvement of the navigation of that river, between Stourport and Gloucester, carried out during the last fifteen years. In this case some difficulty arose, as was anticipated, in making the required excavation for the lock pit. When the sound upper crust of red-brick clay was removed, the impervious blue lias clay beneath, intermixed with black mud and decayed vegetable matter, began to rise in a semi-fluid mass. It was, therefore, determined, that the foundations should be carried down to the sound clay, a depth of 35 feet. For this purpose pits were sunk in the line of the walls, which were filled with concrete, and the spaces between were also gradually, and similarly filled. Eventually, as these walls showed symptoms of being forced inwards, an inverted arch of concrete was carried throughout the whole length of the works. These proceedings were stated to have been very successful.

Mr. E. B. Webb, in his Paper, "On the Means of Communication in the Empire of Brazil; chiefly in reference to the Works of the Mangaratiba Serra Road, and to those of the Mauá, the first Brazilian Railway," showed the roadless state of that country, until within a comparatively recent period. The works described were the first of their class, and hence the mode and the cost of carrying them out, possessed an interest which might not attach to similar works, under more favourable circumstances. The railways now in progress were then noticed, and the important question of State guarantees was referred to. In conclusion, the hope was expressed, that ultimately, Brazil, upon a calculation of the preponderance of good and evil, would not have to regret the epoch, when English capital, energy, and engineering skill, assisted her in utilising her own internal wealth.

The Paper, "On the Construction and Enlargement of the Lindal Tunnel, on the Furness Railway," by Mr. F. C. Stileman, showed how a tunnel originally designed for a single line, had been enlarged to accommodate two lines of railway, the traffic being carried on during the progress of the works. This plan was adopted, in place of a 'twin' tunnel alongside, or of another tunnel at some distance from the original one, as it was found, that it would be more economical, and as it was known, by experience, that there were many inherent disadvantages in working a single-line tunnel.

Although the length of "The Netherton Tunnel Branch of the Birmingham Canal," described in Mr. J. R. Walker's Paper, was only two miles and a half, yet it comprised one-quarter of a mile of embankment, half a mile of open cutting, and a mile and three-quarters of tunnel, besides several aqueducts, bridges, and basins, or docks. Full details were given of the dimensions of each structure, illustrated by copies of the contract drawings, and it was stated, that the total cost of the works had amounted to £200,000.

In Mr. D. K. Clark's Paper, "On Coal-Burning and Feedwater Heating, in Locomotive Engines," the methods introduced, within the last two years, for admitting air above the fuel amongst the combustible gases, in order to prevent the formation of smoke, were described and compared. It was stated, that the use of some of these contrivances was attended by the escape of a considerable quantity of unconsumed air through the flue tubes, and a difficulty in keeping up steam at high speeds; whilst others facilitated the suction of particles of coal through the tubes, and the burning of the smokebox, unless counteracted by an internal arch. It was believed, that by the instrumentality of jets of steam, as a means of inducting and accelerating currents of air, the range, volume, and power of the air currents could be accurately adjusted to the wants of the furnace.

In Mr. Wethered's Paper, "On Combined Steam," it was sought to be established, that there was an advantage in the use of ordinary saturated and superheated steam mixed, over steam simply dried, or superheated; as in the latter case, the temperature of the steam in the cylinder was beyond control, the lubricating materials were liable to be dried up, and the packing and rubbing parts of the machinery to be destroyed. In the course of the discussion it was contended, that the combined system did not possess any peculiar merit over simple superheated steam, except perhaps, that of affording a ready means of regulating the temperature. It seemed to be generally admitted, that there was an economy of at least 15 per cent. in the use of superheated steam, the practical limit to its application being, in giving such an additional amount of caloric, as would permit of the steam remaining dry to the end of the required expansion.

It has been urged as a reproach, that in a country possessing so many interesting works in the department of the Civil Engineer, it is almost vain to look for any record of them, as actually constructed. The collection of such records has ever been a primary object with the Institution, and there are in the Transactions and in the Minutes of Proceedings, several valuable communications of this kind. It cannot, however, be denied, that there are still many important undertakings, some even possessed of great novelty, which have not yet been noticed at the Meetings. It is hoped, that every Member will use his influence to obtain detailed accounts of executed works, which will form, hereafter, a fund of information for the student, and be valuable for reference for the professional man. The record and subsequent publication of the discussions, although now imitated by other Societies, were, for a long time, features peculiar to this Institution, and from which the greatest benefits have resulted, and may still be expected. The discussions are the means of eliciting facts and opinions which might not be otherwise obtained, and are especially useful in calling forth information on matters thought to be too slight and trivial, to form the subjects of Original Communications.

Allusions have, on former occasions, been made to the state of the Library, and to the fact, that the contributions had not kept pace, either with its necessities, or with what might be expected from the large number of Members and Associates who have joined the Institution, and who sign an engagement on their election, to make a donation to the Library within twelve months, in the event of their not communicating a Paper to one of the Meetings.

The Library is now occupying the attention of a Committee, with a view to ascertain what is imperatively demanded, to render the collection of works on engineering and on the allied sciences, as complete as possible. The information thus obtained, will be entered in a MS. List of Books essential for the Library, which will exhibit the deficiencies, and it is hoped, cause them to be supplied. A good collection of books is of paramount importance, and the Council would, therefore, urge every Member to assist in procuring copies of all treatises, reports and documents relating to professional matters, whether published at home, or abroad. It should be remembered, that the Institution is the natural place for their reception and preservation, and that nowhere can they be so beneficially deposited, as where they can be freely consulted by all. This Committee will also report what Atlases, Maps, and Charts should be comprised in the collections; and how they should be arranged, so as to be easy of access. It would be very desirable, that the series of the Ordnance Maps of the United Kingdom, now in the possession of the Institution, should be completed, and that copies of the Maps of the Geological Survey of the British Isles, with which considerable progress has been made, and of those illustrating the great Trigonometrical Survey of India, should also be obtained. Copies of the Reports of the different Railway Companies would be an important addition to the Library, as it is believed, that such a collection would be very useful to Engineers, as well as to the Companies themselves.

Through our Associate Member, Capt. Washington, R.N., the Lords of the Admiralty present annually, the Charts issued under the direction of the Hydrographer; and it is hoped, that this example may be followed by the other departments of H. M. Government.

The mutual interchange of Transactions and Proceedings of other Societies continues; and it will be the constant endeavour to extend this principle. The different series of scientific periodicals are maintained, and it is hoped soon to add to the list, some standard French and German works of this class.

The Catalogue of the Library being now out of print, it will soon become necessary, that a new edition should be prepared; but, as it is an expensive and laborious work, it is thought better to defer its publication until the additions now proposed, are made. In the meantime, the books and other publications will be entered, as received, in the MS. Supplementary Catalogue of the Library.

The tabular statement of the transfers, elections, deceases, and resignations of Members of all classes, during the years 1858-59 and 1859-60, appears thus:—

——	Honorary Members.	Members.	Associates.	Graduates.	Annual Increase.
1858-59.					
Transferred to Members . .	..	..	4		
Elections	1	16	41	..	58 − 21 = 37
Deceases	1	7	9	..	21
Resignations	..	1	3	..	
1859-60.					
Transferred to Members . .	..	..	13		
Elections	..	23	39	..	62 − 26 = 36
Deceases	1	12	7	..	26
Resignations	..	1	5	..	
Members of all Classes on the Books, November 30, 1860 .	24	355	537	14	930

At the close of 1836, when the Institution had existed nineteen years, the number of Members of all classes that had been elected, was 369, and the number still remaining on the books, was 252, or about five-sevenths of those elected. At the close of 1860, these numbers are 1,535 and 930 respectively, from which it appears, that three-fifths of all those elected still belong to the Institution, being a decline of only one-seventh in the relative proportions, after a further existence of twenty-five years.

If the Honorary Members and Graduates are omitted from the calculation, the annual increase of Members and Associates stands thus:—

Years.	Members Elected.	Associates Elected.	Total Elected.	Deceases, Resignations, and Erasures.	Effective Increase.
1855	7	24	31	13	18
1856	10	24	34	24	10
1857	12	57	69	23	46
1858	11	25	36	13	23
1859	16	41	57	20	37
1860	23	39	62	25	37

It should be mentioned, that the average annual effective increase of Members and Associates, during the ten years from 1840 to 1850, was 25; whilst in the last ten years, it has been 27, and in 1859 and in 1860, it has been 37 in each year.

The following Member and Associates, having tendered their resignations, have been permitted to retire from the Institution:— Mr. Heinrich Hubbé, Member; Messrs. George Baker, John Francis Dundas, William Hawes, John Whichcord, and Lieut.-Colonel Henry Cunliffe Owen, R.E., Associates.

The deceases announced during the past year have been:— William Alers Hankey, Honorary Member; William Blackadder, Terence Woulfe Flanagan, Major-General William Nairne Forbes, R.E., Robert Grundy, Joseph Locke, M.P., Charles May, Joseph Miller, Thomas Penson, Robert Berthon Preston, John Geale Thompson, William Francis Isherwood West, and Francis Mortimer Young, Members; Captain William Fullarton Lindsay Carnegie, R.A., Captain Edward Fraser, R.E., Robert Hughes, James Wardrop Jameson, William Sayce, William Simms, and Archibald Slate, Associates.

The Memoirs of our late friends will be found in the Appendix to this Report.

By the death of Mr. Locke, the Institution was deprived of the services of a valuable and influential Member, who was most solicitous to do all in his power to advance the common interests, and to maintain the dignity and social position of the profession. The suddenness of his removal, while in the enjoyment of apparently sound health, and in the full vigour of his intellect, and following so immediately after the deceases of his friends, Brunel and Stephenson, tend to render this loss more severely felt.

The amount of arrears of subscriptions of 1860, still remaining due on the 30th of November, is:—

	£. s. d.	£. s. d.
From Members of all classes, residing abroad	67 4 0	
From Members of all classes, residing in the United Kingdom	180 12 0	
		247 16 0

The amount of arrears for 1858 and 1859, is,—

From Members of all classes, residing abroad	56 3 6	
From Members of all classes, residing in the United Kingdom	78 15 0	
		134 18 6
		£382 14 6

It may be observed, that the arrears of the current year amount to nearly 11½ per cent. of the total sum receivable under the head of annual subscriptions. In this account no notice is taken of the subscriptions of any Member, who is more than three years in arrear, including 1860. As there are several in this position who neither contribute to the funds, nor advance the interests of the Institution in any way, and with whom remonstrance is unavailing, the Council propose shortly to deal with such cases, under the powers given by the Bye-Laws, and to erase the names of the defaulters from the Register of the Institution.

It will be seen by the Abstract of Accounts attached to this Report, that the receipts for subscriptions and fees during the last twelve months, amount to £2,550, being slightly in excess of the previous year. In the same period, the expenditure has been less than the average of the last ten years, not exceeding £2,100. This is, in some measure, due to the fact of the arrears of publications having now been paid for; and for the Minutes of Proceedings alone, the outlay has been less by £500 than in the preceding year. There being thus a balance in favour of the Institution, in addition to the sum of £1,000 already placed on deposit at the Union Bank of London, as mentioned in the previous Report, it was thought advisable, that an investment should be made. The Council, accordingly, resolved to invest £1,000 in Norfolk Debenture Stock, bearing 4 per. cent. interest, which they were enabled to do on advantageous terms. A return has thus been made to a system which was adopted in the early days of the Institution; for so long back as the year 1836, it possessed funded property of its own, to the amount of £535. 3*s*. 8*d*. This was sold out in 1839 and 1840, to meet part of the charges incurred in entering upon the occupation of the present house. The expenses connected with the change of premises from Cannon Row to Great George Street, of building a theatre, and providing suitable accommodation for the business of the Institution; and subsequently, of enlarging the theatre, and partly altering and thoroughly repairing the house, were greater than could be paid for out of income.

Similar demands, though not perhaps in the same form, will, probably, arise in the future; and it is only prudent to endeavour to create a capital, out of which these fluctuating claims may, in part at least, be met.

During the recess there have been paid to the Treasurer, the sums of £2,000 and of £3,000, respectively bequeathed to the Institution by the late Mr. Robert Stephenson, and the late Mr. Joseph Miller. These amounts have been temporarily placed on deposit at the Union Bank of London, where they are now obtaining the current rate of interest, and it will be for the new Council to determine upon their permanent investment.

The funds of the Institution consist of:—

		£.	s.	d.
Bequest from Thomas Telford		4,894	12	11
Donation from Charles Manby . . .		200	0	0
Bequest from Robert Stephenson . .		2,000	0	0
Bequest from Joseph Miller		3,000	0	0
Norfolk Debenture Stock	The property of the Institution.	1,100	0	0
On deposit at the Union Bank		1,000	0	0
		£12,194	12	11

There is also a further sum of £2,000 to be eventually received under the will of the late Mr. Joseph Miller, on the demise of a gentleman residing in the West Indies, who has a life interest in the bequest.

It has been thought, that so munificent a benefactor as Mr. Miller, deserved some memorial; and it was considered, that none more appropriate could be devised, than a portrait to be placed upon the walls of the meeting-room. The Council have confided the task to Mr. Boxall, A.R.A. who will, it may be confidently assumed, produce a good picture on account of his intimate acquaintance with our late Member, and aided by the portrait painted for the family, which was recently exhibited at the Institution.

During the last year Vol. XVIII. of the Minutes of Proceedings has been issued complete, and also in a detached form, portions of Vol. XIX. The Private Press Abstracts of the proceedings at the Meetings, as prepared for the journals, have also been issued weekly during the Session, to such Members and Associates as desired to have them. An authentic account is thus immediately furnished of the communications that are read, and of the discussions upon them, while they are still fresh in the recollection of the Members, by which attention is continually kept alive to the subjects brought before the Institution.

The Bye-Laws require, that the Council shall prepare a list of persons whom they nominate for the several offices of President, Vice-Presidents, and other Members of the Council; and that such list shall be used at the Annual General Meeting for the election of officers. They also direct, that this list shall contain the names of twelve Members and four Associates, although only ten Members and two Associates are to be elected annually. As there are no actual vacancies among the Members this year, it has only been necessary to add the names of Mr. Abernethy and Mr. Bateman, both of whom have consented to act, if elected. The two Associates of Council retire annually. Of the four names now submitted for your consideration,—Mr. H. A. Hunt, Mr. Marrable, Mr. John Cochrane, and Captain Douglas Galton,—the two former were on the list last year.

The steady progress which has marked the career of this Institution from its commencement, shows that its originators were not mistaken, when they believed, that the wants of society demanded some association of the kind, and that the continuance of those wants would produce a state of gradual development. The estimation in which it is held, both at home and abroad, is now universally acknowledged. By unanimity and energy, and by the earnest co-operation of all classes, it should be the constant aim to maintain its high reputation, and to increase its sphere of usefulness. We should ever bear in mind the words of our first President, Telford, delivered in March, 1820, who, on accepting the proffered chair of the infant Institution, said:—

"In foreign countries similar establishments are instituted by Government, and their members and proceedings are under its control; but here a different course being adopted, it becomes incumbent on each individual member to feel, that the very existence and prosperity of the Institution depend, in no small degree, on his personal conduct and exertions."

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS.

Dr.	£.	*s.*	*d.*	£.	*s.*	*d.*
To Balance in the hands of the Treasurer				356	3	1
— Subscriptions and Fees :—						
Arrears	111	6	6			
Current	2,141	9	6			
Subscriptions, 1861 (in advance)	24	3	0			
Fees	192	3	0			
Life	78	15	0			
				2,547	17	0
— Publication Fund				67	10	6
— Council Premium Fund				47	10	0
— Publications :—Sale of Transactions				127	19	6
— Manby Premium				9	12	1
— Telford Fund :—						
Dividends—6 months, due Christmas, 1859, on £2,551. 15*s.* 10*d.*, Three per Cent. Reduced Consols	36	4	1			
6 months, due Lady-day, 1860, on £2,342. 17*s.* 1*d.*, Three per Cent. Reduced Consols	34	8	3			
6 months, due Midsummer, 1860, on £2,551. 15*s.* 10*d.*, Three per Cent. Reduced Consols	36	13	8			
6 months, due Michaelmas, 1860, on £2,342. 17*s.* 1*d.*, Three per Cent. Reduced Consols	33	13	7			
				140	19	7
— Executors of Robert Stephenson :—						
Bequest, free of Legacy Duty				2,000	0	0
— Executors of Joseph Miller :—						
Bequest, free of Legacy Duty				3,000	0	0
— Union Bank of London :—						
Interest from May 29th, 1859, to June 30th, 1860, on £1,000, at deposit				25	16	4
— Norfolk Railway Company :—						
Dividends—6 months, on £1,100, Four per Cent. Debenture Stock, purchased by Order of Council, January 31st, 1860				21	1	8
				£8,344	9	9

from the 1st DEC., 1859, *to the* 30th NOV., 1860.

PAYMENTS.

Cr.	£.	s.	d.	£.	s.	d.
By House, Great George Street:—						
Rent	360	18	0			
Rates and Taxes	43	19	10			
Insurance	18	19	9			
				423	17	7
— Salaries				400	0	0
— Donation to late Cashier and Collector				50	0	0
— Clerk, Messengers, and Housekeeper				152	9	6
— Postage and Parcels:—						
Postage	26	7	5			
Parcels	1	9	3			
				27	16	8
— Stationery, Engraving, Printing Cards, Circulars, &c.				83	13	0
— Coals, Candles, Oil, and Gas:—						
Coals	12	0	0			
Candles	0	17	6			
Oil	2	14	0			
Gas	19	5	0			
				34	16	6
— Tea and Coffee				30	13	6
— Library:						
Books	17	11	1			
Periodicals	22	11	0			
				40	2	1
— Publication, Minutes of Proceedings				736	5	2
— Telford Premiums				8	8	0
— Council Premiums				6	18	4
— Watt Medal				2	1	0
— Manby Premium				10	1	0
— Diplomas				16	18	4
— Manuscripts, Original Papers, and Drawings				5	4	5
— Winding and Repairing Clocks				1	10	0
— Incidental Expenses:—						
Gratuities and Christmas Gifts	1	16	0			
Occasional Assistance	4	4	0			
Assistance at Meetings	9	5	0			
Beating Carpets	1	2	0			
Household Utensils, Repairs, and Expenses	30	11	5			
				46	18	5
				£2,077	13	6
— Norfolk Railway Debenture Stock, £1,100 at 93	1,023	0	0			
Stamps and Commission	10	9	10			
				1,033	9	10
— Deposit in the Union Bank of London, being the Stephenson and the Miller Bequests	5,000	0	0			
— Balance in the hands of the Treasurer	233	6	5			
				5,233	6	5
				£8,344	9	9

Examined and Compared the above Account with the vouchers in the Cash Book, and find them to be correct, leaving a Balance in the hands of the Treasurer of Two Hundred and Thirty-three Pounds, Six Shillings, and Five Pence.—November 30th, 1860.

(Signed) HENRY MAUDSLAY, } *Auditors.*
W. J. KINGSBURY, }
JAMES FORREST, *Secretary.*

December 5th, 1860.

APPENDIX
TO THE
ANNUAL REPORT.

MEMOIRS.

Mr. WILLIAM ALERS HANKEY was born in London on the 15th of August, 1771. He received his education in the University of Edinburgh, and he always referred, with pleasure, to the fact of his having there enjoyed, when a student, the friendship of those eminent men, Dr. Robertson, the Principal, and Professors Dugald Stewart and Dalzel.

Having entered the banking firm of which he subsequently became the head, he early took, and for a long series of years sustained, the leading part in the conduct of its affairs. Although much occupied, he was not content to limit his energies to the mere requirements of business. Gifted with a large share of natural abilities, in combination with great activity of mind, he was qualified for a successful pursuit of literary and scientific objects. And with these, especially within the range of biblical subjects, he always evinced considerable sympathy, not unfrequently contributing to one of the organs of periodical literature. Indeed, to the very close of his life, there was nothing that excited in him a deeper interest than a new reading of the Sacred Text, or a critical note on some passage of the Greek Testament.

But the full amount of his energies was thrown into efforts of various kinds to diffuse moral and religious principles. Hence, in 1801, he joined the Religious Tract Society, and for eight years assisted zealously in its proceedings. It is stated in a published history of the Society, that, on the preparation of some scripture extracts and tracts for the use of the foreign prisoners of war, then in confinement, Mr. Hankey "made one novel and interesting contribution to the Society's work. He mastered Spanish, that he might be duly qualified to revise the tracts in that language for the press, so as to insure their freedom from error."

He also became one of the founders and conductors of the British and Foreign Bible Society; and at the time of his death, Mr. Hankey was, with one exception, the last survivor of the group of excellent men, who, in 1804, publicly launched into existence that invaluable institution. So again, from 1801 to 1832, he actively identified himself with missionary enterprise, voluntarily combining with the office of Treasurer, which he held during the latter half of those years, many of the duties usually devolving upon the Secretary.

These few details will serve to demonstrate the leading features of Mr. Hankey's character. With the good of his fellow-creatures much at heart, he was ever ready, by means of his purse, or his influence, to further any well-considered plans of Christian benevolence. But persuaded, that the spread of religious knowledge, with a view to the extension of religious principles, should be the high aim of the Christian philanthropist, he specially devoted himself to these objects; and during a long life, laboured for them with a perseverance, a singleness of purpose, and a self-denial rarely equalled.

He resided nearly the whole of his life in London, or in its vicinity; and he closed his mortal career in Hyde Park Gardens, on the 23rd of March, 1859, in the 88th year of his age, wearied with bodily infirmities, but, in his own words, "with the mind at peace."

His connection with the Institution dates from a very early period in its history. During the early part of his life, Mr. Hankey resided at Hackney, immediately adjoining the property of the Father of Mr. Henry Robinson Palmer, by whose intelligence and talent he was so much struck, that he interested himself much in his career, and introduced him to Mr. Telford, whose favourite pupil he soon became. He still kept up the communication with his young friend; and when, towards the close of the year 1817, Messrs. William Maudslay, Henry R. Palmer, Joshua Field, James Jones, Charles Collinge and James Ashwell, resolved to form themselves into a Scientific Society,—holding the first Meeting of the Institution of Civil Engineers on the 2nd of January, 1818,—Mr. Hankey encouraged them by every means in his power. In 1820, after the Institution had assumed a substantial form, he joined it as an Associate, becoming, subsequently, one of the earliest Honorary Members, and in the same year, he was elected Treasurer and Banker to the rising Society. This position he held until 1845, when, for the convenience of the Society, the funds were transferred to a West End bank, and the Council instructed "the Secretary to convey, in an appropriate manner, to Messrs. Hankey and Co., the thanks of the Council for the uniform attention shown by them to the interests of the Institution, and to Mr. William Alers Hankey personally, for having so many years filled the office of Treasurer."

Whenever his good offices were needed, the Institution could always count upon them, with as much certainty as could the other Societies of which he was the main support.

Mr. WILLIAM BLACKADDER was born in 1789, at East Blanerne, Berwickshire, and was brought up as a Surveyor and Land Valuer, in the office of his Father, who was a well-known man in that district. In 1810, he went to Forfarshire, to survey the Strathmore estates, at the request of Lord Strathmore's trustees, and he soon obtained such an extensive business, that he settled at Glamis, in that county. There he was not only engaged in surveys, over large portions of the surrounding country, but also superintended the construction of the buildings, roads, &c., required for the improvement of the estates; and he acted as general adviser, in agricultural matters, to the principal landed proprietors in Forfarshire, and in part of Perthshire. From 1825 to 1835, he was occupied in improving the public roads in those counties, and he was called upon to give evidence with regard to them before a Parliamentary Committee. His attention was also directed to the subject of drainage; he deepened and enlarged the River Dean, the outlet from Forfar Loch, which likewise serves as the main outfall of a great extent of land; and he was employed by the late Mr. Robert Stevenson, to take the levels for a proposed canal from Arbroath, by Forfar, to Perth. He was consulted as to the works on the Estuary of the Tay, undertaken by Lord Kinnaird. He also prepared several plans, which were not carried out, for supplying Dundee with water; and at the request of the manufacturers of that city, he matured a plan, which was only partially executed, for increasing the water power of the Dighty. He acted, for many years, for the late Marquis of Bute, and after that nobleman's death, he was appointed by his trustees, the Agricultural Engineer to the Scottish portion of the estates. Several local lines of railway were executed under his direction, and his counsel was always sought by the different companies. He made a survey for a railway through Strathmore in 1833,[1] and for the two branches, the Newtyle and Cupar Angus and the Newtyle and Glamis; he also took an active part in carrying out the Scottish Midland Railway.

Mr. Blackadder was a man of remarkable abilities in the classification of soils, and from his knowledge of botany and geology, combined with his great experience, his views were generally sound and practical. The accuracy of his surveys was universally acknowledged, and his zeal in that respect was so great, that he never commenced his practical labours in the field, without taking the precaution of testing his level by a fixed mark which he established on Glamis Castle.

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[1] "Report relative to the Strathmore Railway, being the extension of the Dundee and Newtyle Railway from Newtyle along Strathmore, between Coupar and Dundee." By W. Blackadder. Tract, 4to. [vol. xii.] Maps. Dundee, 1833.

Among his inventions, may be noticed an instrument for measuring the cubic contents of trees, as also a method of counting their number in thick woods by means of parallel ropes.

He was tall and commanding in person, and he adopted so peculiar a costume, that inquiry was made, on one occasion, whether he was a Scotch bishop. His numerous pockets were generally filled with surveying instruments, and his staff was provided with a hammer at one end and a spade at the other. He was apt, sometimes, to give a personal complexion to public disputes,—a course in which perhaps he was somewhat warranted, by the violent party feuds relative to the Dundee water supply in 1835-36, and the action brought against him, on account of the bursting of an embankment on the River Isla, constructed under his direction. Although, perhaps, too enthusiastic in the cause of his employers, he was both kind-hearted and benevolent, as was proved by the extent of his charities, and he was greatly esteemed for his high integrity. The solace of his latter years was the study of the Greek Testament, and his amusement was the perusal of the classics, which brought back the remembrance of his youth. He died at Glamis, on the 20th of October, 1860, in his seventy-first year, and his remains are interred in the churchyard of that picturesque village.

He had long been connected with the Institution, having been elected a Corresponding Member, in 1836, and transferred to the class of Members, in 1837; but his visits to London were too few and far between, to enable him to take any very active interest in the Society.

MR. TERENCE WOULFE FLANAGAN was born at St. Catherine's Park, Leixlip, Ireland, on the 19th of February, 1819. His early education was received principally at Paris and at Brussels, and in the year 1836, he entered the University of Dublin, where he distinguished himself as a linguist and a mathematician, generally obtaining the first place among his competitors, several of whom are now Fellows of the University. At the close of the year 1837, he became an articled pupil of Mr. Charles Vignoles, (M. Inst. C.E.,) with whom he served five years, during which time he had extensive experience in exploring the country for new railways, and in general Parliamentary work. In 1843, he was appointed Resident Engineer of the Blackburn and Preston Railway, under Mr. Collister, and upon the retirement of Mr. Vignoles, he became the Engineer-in-Chief of the Blackburn Railway Company, and superintended the construction of the lines from Blackburn to Bolton and Clitheroe, which he completed in 1850. He subsequently proceeded to Antwerp, and was engaged about two years, in the construction of the railway between Antwerp and Rotterdam. On the completion of that line, he went to Portugal, where he was occupied, for about two years, on the railway between Lisbon and Santarem. On his return to England in 1857, he took up his residence in London, and was intrusted with the prosecution, before the Parliamentary Committees, of several projected public works, but owing to the monetary crisis at that period, most of them were withdrawn; the only one which he successfully carried, was the Bill for the Kingstown, (Dublin,) Waterworks. In 1859, he was appointed Engineer of the projected Southampton and Fareham Railway, and it was whilst engaged upon the out-door operations connected with this work, that exposure to wet, and subsequent neglect of himself induced a severe illness, from which he never rallied. He died on the 13th of December, 1859, in the forty-first year of his age; having been, for seventeen years, connected with the Institution, which he joined as a Member in the year 1843.

Mr. Flanagan was deservedly respected, by the promoters of the undertakings in which he was engaged, and his loss was severely felt, by a large circle of professional and other friends, who appreciated his possession of those qualities which insure affection and esteem.

MAJOR-GENERAL WILLIAM NAIRN FORBES, of the Bengal Engineers, sixth Son of John Forbes, Esq., of Blackford, Aberdeenshire, was born at that place on the 3rd of April, 1796. He received his early education at home, under a private tutor, except during the winters of 1808 and 1809, when he attended the mathematical and the natural philosophy classes, at King's College, Old Aberdeen. Before going to King's College, and whilst there, his leisure hours were generally occupied in constructing models of various machines, in which he was very successful, notwithstanding the imperfect character of his tools. In 1811, he was sent to the University of Edinburgh, where he studied mathematics and natural philosophy under Professors Leslie and Playfair. At that time, he resided with his relative, the Rev. Archibald Alison, and was the companion of his sons, the late Dr. William Pulteney Alison, Professor of Medicine, and Sir Archibald Alison, the historian. In 1812, he went to Addiscombe, as a cadet, and was presented, in the next year, with a case of mathematical instruments for " his superior attainments in mathematics, as exhibited at the public examination." On leaving Addiscombe, at the end of 1813, he was attached to the Royal Engineer establishment, at Chatham, where his abilities and perseverance attracted the particular notice of the Royal Military

Surveyor. Subsequently, he was employed on the Trigonometrical Survey, in Shropshire and in Wales.

In 1816, he was appointed to the Bengal Engineers, and for several years was Surveyor of Embankments in Bengal and Orissa. In December, 1819, he was ordered to England, to superintend the preparation of machinery for the Royal Mint, at Calcutta. In 1823, he returned to India, in charge of the machinery, and with a recommendation from the Court of Directors, that he should be employed in superintending its erection, and in organising the department. He was, accordingly, appointed Superintendent of the Mint Machinery at Calcutta. Lieutenant Forbes frequently reported to the Government, upon different engineering projects. Amongst others, he prepared a Report on the best means of keeping open the navigation of the stream connecting the Hooghly and the Ganges, which elicited the approval of the Court of Directors.

In November, 1825, his request to be allowed to join the army before Bhurtpore, was granted, on account of his well-known scientific attainments. During this siege, he was temporarily disabled, from having had his right arm and two ribs broken, whilst reconnoitring the works; but he was still able to direct his attention to the mining operations, and he prepared the plans of the unusually large mines, by which the breaches were made, and the fortress was eventually stormed. Lord Combermere, in speaking of Lieutenant Forbes, says, "he was a first-rate Officer of Engineers, and was of the greatest possible use to me during the Siege of Bhurtpore." After the fall of the fortress he resumed his duties at the Mint.

In the years 1832 and 1833, Captain Forbes was employed, in conjunction with Colonel Macleod and Captain Fitzgerald, on a survey for a navigable canal from Rajmahal to Calcutta, for which he, subsequently, submitted an elaborate project; and in June, 1836, he was appointed Master of the Mint, at Calcutta.

In 1847, he acted, for five months, as Member of the Military Board, during the absence of the Chief Engineer. In December of the same year, he was specially instructed to proceed to England, in order to be appointed Member of a Commission assembled to inquire into the constitution of the Royal Mint. This duty being completed in April, 1849, he returned to India and resumed his duties at the Calcutta Mint, which office he continued to hold, until he finally quitted India.

Up to 1854, his health had been remarkably good, having been but once absent on sick leave, and then only during two months in 1828. In the course of 1854, he frequently complained of exhaustion, almost amounting, at times, to a complete prostration of strength; still his mental energies never gave way, he attended daily at the Mint, and he drew the plans for the new Post Office. In November, he was suddenly seized with spasm of the heart, and in the early part of 1855, he was compelled to obtain leave to return to England. He accordingly embarked on the 9th of April, on board the 'Oriental,' but he did not live to complete the voyage. He died on the 1st of May, 1855, off the island of Tibble Teer.

His commissions bear date:—Ensign, 1816; Lieutenant, 1818; Captain, 1827; Major, 1839; Lieutenant-Colonel, 1841; Colonel, 1851; and Major-General, 1854.

In 1819, by order of the Marquis of Hastings, he prepared plans for a cathedral at Calcutta, but its erection was not sanctioned by the Court. Subsequently, at the request of the late Bishop of Calcutta, he undertook the construction of the present cathedral, of which the first stone was laid in 1839, and the building was completed in 1847. He expended much time and labour on this work, which he undertook in addition to his ordinary important duties; and the gratitude of the late Bishop was unbounded. The great esteem in which General Forbes was held by his fellow-citizens, is proved by the erection in the cathedral, by public subscription, of a monument to his memory. A bust of him has also been placed by the Government in the Calcutta Mint, where he was beloved and respected by all the officers and workmen of the establishment.

General Forbes had been connected with the Institution of Civil Engineers for thirty-five years, having been elected a Corresponding Member in 1820, and transferred to the class of Members in 1828. He was also a Member of the Geological Society, the Asiatic Society, the Institut d'Afrique, and other scientific societies. In addition to those branches of engineering, upon which, from his official duties, he was more immediately employed, he evinced a lively interest in many others, more especially in the progress of steam communication, and the question of town drainage. He possessed indomitable energy and determination, and in whatever branch of his profession he had embarked, he would have been equally successful. He was highly esteemed in the service of which he was an ornament, and in the circle of his private friends his loss was deeply regretted.

Mr. ROBERT GRUNDY served a regular apprenticeship in the works of Mr. Elijah Galloway and of Messrs. Seaward from 1829 to 1834. He was afterwards employed at the Woolwich Dockyard, and subsequently by Messrs. Fawcett, Preston, and Co., of Liverpool, by whom he was sent, in 1839, to Rio de Janeiro, where he acted, for several years, as Chief Engineer to the Brazilian Mail Steam Packet Company. During this period, Mr. Grundy accompanied the Emperor of Brazil, on a tour through a portion of His Majesty's dominions, as Engineer-in-Chief, there being several steam vessels in the fleet; and for his services on that occasion he received the title of 'Cavalheiro da Ordem da Rosa.' He then visited England for about a year, and having been appointed, in 1848, Chief Engineer of the Arsenal da Marinha, at Rio, he returned to Brazil in the steam ship 'Don Alfonso,' belonging to the Brazilian Government. It was when this vessel was on her trial trip, off the Great Orme's Head, near Liverpool, having at the time a distinguished party on board, that she was the means of saving, from the American emigrant ship 'Ocean Monarch,' then on fire, upwards of one hundred and sixty souls; and in the rescue of the perishing people, Mr. Grundy afforded most active co-operation.

Able and zealous in the performance of his duties, and ready and willing for any service, Mr. Grundy became extremely useful to the Brazilian Government, both as a Mechanical Engineer and as a Naval Architect; and he succeeded in winning the esteem of his superiors, who placed implicit confidence in his judgment. He held the rank of Lieutenant in the Brazilian Navy, and was always in charge of the engines during the marine excursions of the Emperor. He lived, for some years, on the island of Sapocaia, in the Bay of Rio, where he hospitably entertained many of his countrymen.

In 1856, he was sent by the Government, to superintend the arsenal at Bahia, at which place he died in 1859. He was elected a Member of the Institution in 1854, but he never enjoyed any opportunity of attending the Meetings.

MR. JOSEPH LOCKE, M.P., one of the sons of Mr. William Locke, the Mineral Agent of the Duke of Norfolk, Lord Stourton, and other colliery owners, was born at Attercliffe, near Sheffield, on the 9th of August, 1805. He received the rudiments of education at the Grammar School at Barnsley, where his father then resided; but the greater part of his time being of necessity devoted to employments little in accordance with his ultimate career, his subsequent scientific acquirements may be said to be entirely due to his own industry and desire for knowledge, fostered by the judicious and skilful guidance of Mr. Thomas Tate, who, in writing of him, says:—"I first met Mr. Locke at Newcastle-upon-Tyne, about the year 1823. He was then a pupil of Mr. George Stephenson's, and was occupied during the working hours of each day on his duties at the Locomotive Manufactory. He was a very active youth, fond of athletic exercises, in which he excelled;

but the chief part of his leisure time was devoted to the study of Mathematics, under my superintendence, and I was so struck with the energy with which he pursued his studies, his quickness of comprehension, and his indomitable perseverance, that I foretold, even at that early period, that he would take a leading position in the profession for which he was destined."

At the age of fourteen he was placed with Mr. Stobart, a 'colliery viewer,' at Pelaw, in the county of Durham, with whom he remained about two years, and then returned to Barnsley to pursue the same occupation for twelve months under his father.

Between the families of the Lockes and the Stephensons there had long existed an intimacy, which resulted in Joseph Locke being received in 1823 as a pupil of George Stephenson, and his being placed at the Engine Factory at Newcastle-upon-Tyne, where congeniality of tastes and pursuits induced the friendship with Robert Stephenson which, with slight intermission, continued throughout their lives. Here he had full opportunity of studying the locomotive engine, then comparatively in its infancy, and of satisfying himself of its capabilities; and all his leisure hours were devoted to the acquisition of Mathematics, and generally to supplying the deficiencies of education which he then perceived. This feeling probably induced his taking a very active part in establishing the Mechanics' Institution at Newcastle-upon-Tyne; and on the occasion of a public meeting for promoting that object, when George Stephenson occupied the chair, Joseph Locke, in moving one of the resolutions, endeavoured to shadow forth the advantages to be anticipated from the cultivation of mechanical knowledge, and especially the devotion of attention to the subject of railways, then about to be introduced for general traffic. This was his first appearance in public.

The first civil engineering work upon which he was engaged was the construction of a railway of six miles in length from the Black Fell Colliery to the River Tyne, of which George Stephenson was the Engineer, and there he acquitted himself so well, that he was subsequently sent, in 1825, to survey the lines from Leeds to Selby, from Manchester to Bolton, and from Canterbury to Whitstable.

In 1826 George Stephenson became the Chief Engineer of the Liverpool and Manchester Railway, and he immediately selected Joseph Locke as one of the Resident Engineers, a position which he continued to fill until the completion of the line. The attention previously devoted to the capabilities of the locomotive engine now came prominently into play, and in the controversy which ensued upon the Report of Messrs. James Walker and J. U. Rastrick, recommending stationary power for working the line, Joseph Locke took a prominent part; and in the pamphlet written by Robert Stephenson and himself in 1828 the question of the future motive power of railways was virtually set at rest. It was conceded that rope traction might and would still continue to be used in exceptional cases, but it was contended that the locomotive must become the inevitable power. Full confidence was not, of course, immediately accorded to the new machine, and easy gradients were at first generally considered indispensable, but Mr. Locke felt and expressed great confidence in the possibility of working steeper inclinations than he was ever permitted to try; and in after-times he always boasted of having been systematically the hardest task-master of the locomotive, by eliciting all its powers to overcome the gradients he had submitted to it.

In the year 1829, having intrusted to him other professional duties, in addition to those on the Liverpool and Manchester Line, then drawing to a close, he surveyed the Manchester, Stockport, and Whaley Railway.

The opening of the Liverpool and Manchester Railway took place on the 14th of September, 1830, and its success establishing confidence throughout the district, numerous schemes were proposed, for some of which Mr. Locke made surveys. Among them may be mentioned lines from Manchester to Sheffield by Stockport; from Manchester to Leeds; from Huyton to the North of Liverpool, &c.; but the enterprise to which he especially devoted himself was the survey of the line which, branching from the Liverpool and Manchester Railway at Warrington, was intended to run to Birmingham, and to form the main link in the chain between Liverpool and the Metropolis. Circumstances contributed to oppose the facile accomplishment of this project, and in the meantime Mr. Locke examined a line from Limerick to Waterford in 1831, and from Dublin to Kingston in 1832. In the years 1832-33 the project for the line between Warrington and Birmingham, then designated the Grand Junction Railway, was seriously revived, the Bill was carried, and in 1834 Mr. George Stephenson and Mr. Joseph Locke were appointed joint Engineers for the line. In the following year (1835), on the resignation of Mr. Stephenson, the position of Engineer in chief was confided to Mr. Locke, and so strenuously did he devote his energies to the work, that the line was completed and opened for traffic on the 6th July, 1837. There were on the line some heavy works, such as the Dutton and the Vale Royal Viaducts; and it was on this railway that the heavy double-headed rails,—the wooden trenails,—and the wooden keys for securing the rails in the chairs were first used.[1] The important feature, however, was the completion of the line within the estimate, and at a cost of between £14,000 and £15,000 per mile. This commercial result was seized upon by the speculative community, and upon the faith of Mr. Locke's reputation as an economical engineer, capital could always be found for undertakings of which he assumed the direction. Professional engagements were therefore pressed upon him.

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[1] *Vide* Minutes of Proceedings, Inst. C.E. vol. xvi. p. 293-4.

In 1837 the Lancaster and Preston Railway was commenced; and in the same year his aid was secured for carrying out the London and South-Western Railway, which had been commenced some time previously by Mr. F. Giles. Both these lines were completed in the year 1840; and to the latter, a large proportion of Mr. Locke's time was devoted, as he foresaw the extensions that would probably ensue to the south and the west of England, and the influence that must be exercised in directing commercial relations between Paris and London, through Rouen, Havre, and Southampton. On the South-Western Railway there are not many interesting works of engineering skill, excepting some deep cuttings, and the Micheldever embankment, near Winchester, which is 90 feet in height. The Sheffield and Manchester Line was also commenced by him in 1838.

For some time a body of capitalists, in Paris, represented by Messrs. Charles Laffitte and Edward Blount, had contemplated a railway between Paris and Rouen, and the overtures which were made to Mr. Locke resulted in his assuming, in 1841, the direction of the line, of which Messrs. Brassey and Mackenzie became the contractors. This was followed, in 1843, by the extension of the line from Rouen to Havre, and in 1852 by the line from Mantes to Caen and Cherbourg, affording direct communication between the capital and the chief naval arsenal of France. He also projected the Railway from Paris to Lyons, which was subsequently carried out by the Company in which M. Paulin Talabot has taken so distinguished a part. The advent of Messrs. Brassey and Mackenzie, with their gangs of navvies, and all the means and appliances so entirely novel to the comprehension of the native workmen, created for a time a panic, which was, however, soon succeeded by a feeling of the most unbounded confidence, both in the ruling spirit and the satellites, and eventually whatever was ordered was as readily obeyed by the French as by the English workmen. That this feeling of confidence was mutual, and extended to the highest ranks, was demonstrated by the fact, that on the falling of the Barentin Viaduct, on the line of the Rouen and Havre Railway, Mr. Brassey, without waiting to discuss the question of liability, but acting on the suggestion of Mr. Locke, immediately commenced the reconstruction, leaving to the Engineer and the Directors to settle for him the amount of allowance to be made; and in this he was right, as the Directors, viewing the occurrence as an inevitable casualty, awarded such an indemnity as was just to all parties. For these lines was established the extensive Engine Factory at Sotteville, near Rouen, under Mr. Buddicom, (M. Inst. C.E.,) and the late Mr. W. Allcard, (M. Inst. C.E.,) which, following upon the labours of Messrs. Manby, Wilson, and Co., at Charenton, has given such an impetus to the construction of engines and machinery in France.

During these extensive foreign engagements Mr. Locke found it essential to associate with him an Engineer to whom he could confide the direction of his home labours, which were fast augmenting. In the year 1840 he was therefore joined by Mr. J. E. Errington, (V.P. Inst. C.E.,) with whom he had worked and had been partially connected since the year 1829. With his aid the Parliamentary labours and contests were carried on, and the works were executed for a multitude of lines, among which it will suffice to mention:—the Scottish Central;—the Midland Junction;—the Kendal and Windermere;—the Caledonian:—the Lancaster and Carlisle;—the East Lancashire;—the Scottish Midland;—the Aberdeen; the Perth and Inverness;—the Dundee and Perth;—the Ormskirk;—the Blackwall extension, to Bow;—the Royston and Hitchen;—the Royston to Shepreth;—the Crewe and Shrewsbury;—and the Salisbury and Yeovil Railways; with many others;—as well as the Greenock Railway and Docks; and the Dutch Rhenish Railway in Holland, and the Barcelona and Mataro Railway, in Spain, on which latter line his favourite coadjutor, Mr. A. S. Jee lost his life.[1] The unity of feeling between Locke and Errington, respecting the mode of conducting works, insured success, and their connection continued from the first with unbounded confidence and mutual pleasure and advantage, until the period of the decease of Mr. Locke.

On most of these lines steeper gradients were adopted than were advocated by other engineers; but Mr. Locke remained unshaken in his confidence in the powers of the locomotive engine, and to this, in a great degree, may be attributed his general success, and the economy of construction of his railways.

In addition to this long list of works actually executed, it must be remembered, that Mr. Locke was engaged, in common with the other leaders of the Profession, in a multitude of Parliamentary struggles, for which his coolness and steadiness as a witness, his caution and judgment, and his readiness of conception, peculiarly fitted him. Among these the 'Battle of the Gauges' must not be forgotten. His early feelings with respect to the locomotive engine never quitted him, and he took great interest in the works at Crewe, discouraging the introduction of a diversity of engines of various forms and from numerous makers, and insisting upon the good system of uniformity in the greater number of the parts composing the engines, in order to insure economy, as well as the utmost promptitude in repairs. This system, hitherto so little attended to, and yet of so great value, especially on Indian and Colonial Railways, is not sufficiently understood by the Directors of those undertakings.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xviii., p. 193.

It has been said of Mr. Locke, that he has not left any monumental works behind him; and this is true. He has not constructed any such works as the Menai, the Britannia, the Victoria, or the Albert Bridges, nor such as the 'Great Eastern' steam-ship, but he has left behind him as long a list of useful works as any of his compeers, and most of them have proved commercially profitable investments. It has been appropriately said of him:—"The peculiar characteristic of Locke's career was the firmness and decision with which throughout all his projects he avoided the construction of great and too costly works. His viaducts were of ordinary dimensions, though some of them were of admirable construction—such as those across the bold ravines of the north of England and Scotland. In every case they are exactly fitted to the places they occupy; and in the same manner his bridges over the Thames and the Seine are distinguished for their adaptation to their position, the lightness and simplicity of their construction, and the elegance of their design.

"An Engineer with such qualifications, and so recommended to shareholders by his caution and judgment, united to his great talents, had naturally an eminent career before him. In common with the most fortunate of his profession he enjoyed golden opportunities, and in conjunction with Stephenson and Brunel more particularly, he may be said to have completed the triumvirate of the engineering world."[1]

Mr. Locke entered Parliament in 1847, as M.P. for the Borough of Honiton, where he possessed a large landed estate. He was a decided liberal in politics, and steadily supported his party on all great questions, chiefly however only addressing the House on subjects of which he possessed a special knowledge, when he commanded general attention.

For his services in connection with railways in France, he received the Cross of the Legion of Honour from King Louis Philippe, and was created an Officer of the Order by the Emperor Napoleon III.

He was a Fellow of the Royal Society, and he joined the Institution of Civil Engineers, as a Member in 1830; was elected

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[1] "The Times," September 21, 1860.

Member of the Council in 1845, became a Vice-President in 1852, and held the position of President during the years 1858 and 1859.

It is seldom that so much life and intense energy are combined with the physical power of working mentally and bodily for a long continuous period without severe reaction; yet this power was possessed by Mr. Locke, and to his habit of seeing for himself all his difficult works, under all their phases, may in a great degree be attributed their almost invariable freedom from accident.

Mr. Locke's active habits and his naturally good constitution would have insured confidence in his enjoying a more than ordinary length of days; and until after the accident in the tunnel, during the construction of the Cherbourg Line, where his leg was severely fractured, he showed but little signs of age, or of the labours he had undergone. It was, therefore, with the utmost surprise, that the news was received of his sudden attack, confirmed within a few hours by the intelligence of his decease. He was staying at Moffat, near Dumfries, for the purpose of shooting in Annandale, his usual custom for many years past, when very early on Monday morning, he was seized with acute internal inflammation, against which the best medical advice proved unavailing, and he sunk and expired on Tuesday morning, the 18th September 1860, at the early age of fifty-five years.

Mr. Locke's extensive professional practice would have sufficed to render him a rich man, but he had moreover the talent of making good investments, and not having any family, or any causes of expense, he became a very wealthy man, and at his death the administration of this large accumulation devolved upon Mrs. Locke, who, though suffering from habitual ill-health, has most praiseworthily undertaken to carry out what she knew to be the intentions, or desires of her late husband, although he had omitted to record them in his will. Hence the munificent gifts to his family and friends and assistants, as well as those to the town of Barnsley, in the form of a park, a recreation ground, an endowment for the Grammar School, where Mr. Locke received his education, and a donation to the Roman Catholic Schools of that district, although neither he, nor Mrs. Locke were members of that Church. Other equally liberal intentions with respect to public institutions are spoken of, which will be, without doubt, duly confirmed.

At a numerous meeting of noblemen and gentlemen, at the Institution of Civil Engineers, it was resolved to raise a statue to the memory of Mr. Locke, and permission was requested for placing it beside the statues of Stephenson and Brunel, in St. Margaret's Gardens, Westminster; this permission was not, however, granted by the Government, and the work of Baron Marochetti will be transferred to the "Locke Park" at Barnsley; permission has been, however, accorded by the Dean and Chapter to Mrs. Locke to place a window, to the memory of her husband, in the Abbey at Westminster.

Thus passed away within a few short months the third of the leaders of the Engineering world:—Brunel, Stephenson, and Locke:—they were born within two years of each other, and within the same space of time they were all removed. They were intended to execute certain purposes, and having worthily fulfilled their mission, they were removed by the same all-wise Providence who rules all things for the general good.

Mr. CHARLES MAY was born at Alton, in Hampshire, in the year 1800. His parents were members of the Society of Friends, and his early education was only such as was then given to the sons of country tradesmen, connected with that religious body. At a comparatively early age, he was articled to a chemist in Stockport, and on finishing his apprenticeship, he commenced business on his own account, at Ampthill, in Bedfordshire. There he gradually added the manufacture to the selling of drugs; growing the herbs, and exercising his mechanical ingenuity in the construction of machines for grinding, and the apparatus necessary for the chemical extraction of oils and essences. These employments, did not, however, furnish sufficient scope for his love of mechanics, and ultimately, he added a general millwright's shop to his other business. He had, from an early period, been an earnest advocate of high-pressure steam, used expansively, for promoting economy in the saving of fuel; and among his early but first works, was the construction, partly with his own hands, of an engine for driving a saw mill at Luton, to which he applied this system with signal success. That engine has only, since his decease, been superseded by one of larger construction. He was also a strenuous advocate for the use of the 'steam jacket' at a time when manufacturing engineers, from the slight additional difficulty of construction it involved, resolutely opposed its introduction. Among the many works, which he executed, while at Ampthill, was the Observatory of Dr. Lee, at Hartwell; and from that time may be dated his intimate connexion with the astronomical world, in which, to the end of his career, he took a well-known and prominent interest. Anxious to extend his chemical business, he determined to establish a branch in London, for grinding drugs without adulteration. For this new concern, he made his own machinery, and so well did he succeed, that this effort laid the foundation of his future success, in the new path which soon opened before him.

In 1836, Mr. May became a partner in the well-known firm of Messrs. Ransomes, at Ipswich; and the rapid extension of that business, during the period of his connection with it, was matter of more than local knowledge. While there, Mr. May invented the method of compressing the wooden treenails used as fastenings for railway chairs, a system which has been all but universally adopted, on both British and foreign lines. During the same period, under the superintendence of Professor Airy, F.R.S., (Hon. M. Inst. C.E.,) the Astronomer Royal, he constructed, with an accuracy never previously attained, the great transit circle, and the altazimuth, at the Greenwich Observatory. He also erected an observatory for his own use, and furnished it with a transit instrument and clock, and a Merz achromatic telescope, 6½ inches in aperture. Amongst other improvements introduced by him, may be cited the process of 'chilling,' for the pivots of large instruments.

In the year 1851, the wider scope presented for the branches of engineering and the theoretical department to which he had devoted himself, induced him to settle in London, where, for a short time, he was in partnership with Mr. Hawksley (M. Inst. C.E.). That connection was soon dissolved, and Mr. May's individual practice so rapidly increased, that for many years before his death, there were few important lawsuits, connected with patents, on which he was not consulted, and he was engaged, either on one side, or the other, in most of the contested engineering cases involving important results. Mr. May was a Fellow of the Royal Society, and of the Royal Astronomical Society. His connection with the Institution of Civil Engineers dated from 1836, when he became an Associate; in 1846, he was transferred to the class of Members, and in 1848, he was elected a Member of the Council, upon which he served up to the end of 1855. He was a very regular attendant at the Meetings, and he frequently took part in the discussions, his observations being characterised chiefly by their practical bearing. He was a natural mechanic, and he possessed perseverance in the acquisition of knowledge, which would have enabled him to take a high position in the engineering world, if he had been regularly brought up for the profession.

He was much esteemed by his family and friends, who were grieved by seeing him for some years gradually sinking under a painful disease, which eventually proved fatal on the 10th of August, 1860.

MR. JOSEPH MILLER was born at Carlisle, in the year 1797, and he there received the ordinary education of the period, no special attention being devoted to the direction of his studies, although the bent of his mind was sufficiently evident, as from a very early period he was a thinking, meditative boy, avoiding the companionship of children of his own age, and seeking the society of men, from whom he could learn something connected with his favourite study—the construction of machinery. He thus early became thoroughly acquainted with the mechanism and the theory of the two Boulton and Watt steam-engines, then working in Carlisle. Great interest was at that time requisite to enable an apprentice to be received in the already celebrated Soho Works; but on Mr. James Watt having laid before him the memorandum-books and sketches of the would-be engineer, and finding from his conversation that his acquirements were above the average, he consented to his being articled to the firm, and Joseph Miller entered the Soho Works at the age of about fifteen years. His mother having died when he was very young, his father went to America, to prosecute a claim to an estate which he eventually recovered through the influence of President Jefferson; thus young Miller was left to fight his way alone and without any aid, save that of his own persevering spirit. Soon after his admission to Soho, John Barnes, a godson of Mr. Watt's, was received there as an articled pupil, and between these two young men, of very nearly the same age, an intimacy sprung up, which in after-years ripened into a sincere friendship, and ultimately led to their partnership in business. Their tastes were similar, and they pursued their studies and took their recreations together. Their progress in the acquisition of mechanical knowledge was very rapid, and when it was deemed advisable that Barnes should go to Edinburgh to study at the university, he was very anxious that his friend Miller should accompany him. This could not however be accomplished, and Miller remained at Soho, where, under the able tuition and guidance of Murdoch, Southeron, John and Henry Creighton, Brown, and others, whose names are intimately connected with the early history of the steam-engine, he rapidly acquired a degree of proficiency which, in 1817, at the early age of twenty years, induced an offer from the late Mr. Jessop to intrust to him the management of the mechanical portion of the Butterley Iron Works. That offer he accepted, and he thus had ample scope for the exercise of his talents; and the steam-engines designed by him soon deservedly acquired a high reputation. He there adopted the use of steam at an increased pressure, working with expansive gearing; and not only in the construction of the engines, but in the consumption of fuel, he arrived at considerable economy. This principle he extended to the marine engine constructed at Butterley for the 'Lord Melville' and the 'Royal Sovereign,' vessels which, under the guidance of Messrs. Jolliffe and Banks, formed the nucleus of the General Steam Navigation Company.

About the year 1820, Mr. Barnes, who had been commissioned to superintend the construction, at Butterley, of a pumping-engine on the Cornish principle, visited the works, and renewed his acquaintance with his former friend, who was then married and apparently settled. Mr. Barnes there met the sister of Mrs. Miller, whom he eventually married, and this additional bond doubtless contributed to induce the proposition on his part for Miller to join him in establishing in London a manufactory for marine steam-engines. This project was accomplished in 1822, and between that period and the year 1835, when the partnership was dissolved, both Barnes and Miller were very actively and successfully engaged in the production of marine engines, for the numerous steam-packet companies then springing up on all sides. The new factory was established in Glasshouse Fields, Ratcliff; and for the Southampton and Havre, and the Dover and Calais stations, they were early and fully engaged. Barnes and Miller next turned their attention, so early as in 1826-27, to the navigation of the River Soane, where they attained great success, which led to their being employed on the Rhone, where, with their vessel the 'Pioneer,' they succeeded for the first time in navigating that river without assistance from the shore.

In the Memoir of Mr. John Barnes there occurs the following passage:[1]—

"Before this period (1826-27), the introduction of steam power for the propulsion of passenger vessels on the Rhone and the Soane, had been scarcely deemed practicable, and the endeavour to employ it for towing barges, had been attended with very moderate success. When attempted by some French Engineers, by Messrs. Manby, Wilson, and Co., of Charenton, and by Messrs. Steele and Atkins, of La Gare, a member of this latter firm was killed by the explosion of the boiler, in an attempt to propel the vessel against the stream; and the Writer of this memoir (who had gone on board to aid his countrymen in overcoming a difficulty,) only saved his life and those of his workmen, by ordering them in great haste from the boat, on perceiving that the working engineer had fastened down the safety-valve, by a strut between the end of the valve lever and the deck carline; the explosion occurred, before the party reached the shore, and the unfortunate cause of it perished, with a number of persons of some importance in Lyons.

"This catastrophe and the general indifferent success of the previous attempts, had so depressed all speculative enterprise at Lyons, that when a Company was formed, for the navigation of the Rhone, Messrs. Barnes and Miller felt themselves called upon to make a considerable investment in the affair, to impart to it some degree of confidence, which still was very wavering; when however, on the first upward voyage, intelligence was sent by courier, from each station, that the steamer was overcoming all difficulties, the value of the shares rose, as the solution of the problem approached, and when the boat reached Lyons, in two days less than the time guaranteed by the Engineers, the securities had reached a premium, and were eagerly purchased from Messrs. Barnes and Miller, who immediately secured extensive orders for engines and machinery for France, and subsequently for this country, where the reputation of the machinery from the works thus established, has been worthily maintained to the present time."

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[1] *Vide* Minutes of Proceedings, Inst. C.E., vol. xii., p. 140.

Extensive engagements followed rapidly, and the Mediterranean packets from Marseilles soon afforded them a large sphere of action. Then the Havre boats occupied their attention; and in 1834 the series of Star Company's Gravesend packets was commenced by the construction of the engines for the 'Comet,' the 'Star,' and the 'Planet,' vessels which attained speeds previously considered impracticable, and which subsequently, between 1837 and 1852, in the 'Vesper,' 'Satellite,' 'Meteor,' 'New Star,' 'Jupiter' and 'Mars,' was raised to upwards of fifteen miles per hour. Early in the year 1835 the partnership with Mr. Barnes was dissolved, and Mr. Miller, having become the purchaser of the establishment in Glass-House Fields, was joined in March of that year by Mr. Richard Ravenhill. The firm of Miller, Ravenhill, and Co. continued until the year 1846, when, by the introduction of Mr. Salkeld, who had been connected with them for some years, the firm became Miller, Ravenhill, and Salkeld.

In 1835 the 'Iberia,' the first vessel of the fleet of the Peninsular and Oriental Company, was intrusted to the firm, and Mr. Miller exhibited his usual skill in the engines, as in 1840 he did in the oscillating engines of large size for the 'Ripon,' the 'Indus,' and the 'Pottinger,' the first iron vessels constructed for that Company.

In the year 1844 the firm secured the services of Mr. Pasco as their naval architect, and at their new waterside premises at Blackwall, they subsequently constructed some very successful iron steamers, which attained great speed; the 'Prince of Wales,' London and Margate packet, reached upwards of sixteen miles per hour, which was considered very remarkable, until in 1846, the 'Llewellyn' Holyhead mail packet attained, on her trial trip, a speed of upwards of eighteen miles per hour. In 1835 the 'Tancrède' and the 'Léonidas' were constructed for the French Government Post-office service in the Mediterranean; then followed the 'Ichnusa,' a vessel fitted with Morgan's feathering paddle-wheels for the Sardinian Government; and in the year 1843 the engines of the 'Cuvier,' French vessel of war, were confided to the firm, whose reputation was at its zenith.

Many other equally successful works were also accomplished, such as the Mediterranean packets the 'Phœnicien,' the 'Phoca,' and the 'Charlemagne' between 1836 and 1840; and the

'Argonaut,' the 'Pylades,' and the 'Orestes,' in 1840, for the Russian Government, for the navigation of the Black Sea.

The navigation of the Rhine had been often attempted, but only with comparatively indifferent success. Mr. Miller studied the case carefully, and in 1837 supplied the engines for the 'Herzog von-Nassau,' and in 1839 for the 'Comet;' in the latter year he also constructed the engines for the 'Victoria,' an iron vessel, built by Ditchburn; and in 1841, for the 'Elberfeld,' another iron vessel by the same builder. Between 1844 and 1847 were also constructed the engines for the new 'Elberfeld,' the 'Concordia,' and the 'Joseph Miller,' for iron vessels designed by Pasco, which attained great success. It was on board of one of these vessels, of very light construction, and drawing only a few inches of water, that Mr. Miller nearly met his death. He had invited a party of select friends, comprising Mr. Thomas Landseer, with his wife and cousin, Messrs. C. Landseer, T. H. Wyatt, the late Frank Stone, R. Perring, and some others, to accompany him in a trial trip from the Thames to the Rhine; and when about mid-channel, foggy and heavy weather came on, which obliged them to lie off the coast until daylight. The slightly-built vessel showed signs of weakness amidships, and would doubtless have broken up, under such a heavy trial, but for the presence of mind of Mr. Miller, who, although suffering severely from rheumatic gout, calmly ordered timber struts to be placed between the boilers, and between them and the sides of the vessel, and then, with a chain and screw-coupling, to brace all together, thus the buckling of the sides of the vessel was prevented and the mouth of the river Rhine was safely reached, contrary to the anticipations of many on board, who had given up all hope of ever again seeing terra firma.

So early as in 1842 the engines of the 'Trent' and the 'Isis' were built for the Royal West India Mail Packet Company, and these were followed in 1852 by the oscillating engines with feathering paddles for the 'Solent,' and the 'Tyne,' for the same company; vessels of 1,800 tons burden, which, with only 400 H.P., attained respectively, on their trial trips, the speeds of 13·945 knots and 14·6 knots per hour.

When every Steam Packet Company in England, and every foreign government had become fully convinced of the excellence of the engines designed by Mr. Miller, the authorities at the Admiralty awoke to the probable utility of trying his skill, and in 1835 a pair of engines of 120 H.P. were allowed to be put on board H.M. ship 'Blazer,' then followed in—

1837	the 'Tartarus,'	120 H.P.
1841	the 'Infernal,'	320 „
1842	the 'Gladiator,'	400 „

The two latter pairs of engines were on the direct-action principle, and those for the 'Gladiator' had the air-pumps placed at an angle, an innovation which arose from an accident. When Mr. Miller sent in the design for these direct-acting engines with the air-pumps placed vertically and side by side between the cylinders, an objection was raised, that the engines occupied so much space athwart ships that the guns could not be trailed fore and aft. Mr. Miller, being determined to meet and conquer the objection, instantly produced another design, in which the cylinders were brought up close together, and the air-pumps were worked fore and aft in inclined positions to the main shaft, thus inducing an improved design of engine, whilst defeating a less worthy design of another kind.

. Between 1844 and 1847 were produced the engines for H.M. ships 'Amphion'—the first direct-acting horizontal screw-engines placed beneath the waterline, for the British navy—the 'Minx,' 'Teazer,' 'Rifleman,' 'Sharpshooter,' 'Plumper,' 'Triton,' 'Basilisk,' 'Furious,' 'Valorous,' 'Buzzard,' and 'Barracouta'—a goodly list, and all of successful engines.

It should be noted that the original notion of the 'Amphion's' engines, as a means of driving the screw-propeller, then a new introduction, direct and without the intervention of gearing, and so placed as to be underneath the waterline, was submitted to the Lords of the Admiralty, by Count Rosen: this crude idea was also laid before Mr. Miller, who willingly undertook to arrange the details, and be responsible for the action of the machinery, the order for which was forthwith given to Messrs. Miller and Ravenhill, who had thus the merit of introducing a most useful innovation into the Royal Navy.

The part taken by Mr. Miller in the introduction of the Screw Propellor should not be forgotten. In 1837 he was consulted by Mr. F. P. Smith, and was much pressed to construct the engines and machinery for the 'Archimedes,' which was designed by Pasco and built by Wimshurst in 1838. Being, however, too much occupied to undertake the construction of the engines within the desired period, Mr. Miller could only give his friendly advice to the ingenious projector of the novel system of propulsion, and it was only in 1839 that Messrs. Miller and Ravenhill had intrusted to them, with the consent of Messrs. Rennie, the contractors, the repairs of the boilers and engines of the 'Archimedes' after an accident. From that period Mr. Miller's attention was devoted to the subject of screw propulsion, and to such an extent did he carry his enthusiasm, that he spent nearly three months on board of H.M. ship 'Amphion,' when on foreign service, for the purpose of fully examining the working of the new propeller under all circumstances. Indeed it may be doubted whether even the determined energy of Mr. F. P. Smith would have been successful in the introduction of the Screw Propellor to H.M. navy, had not such men as Joseph Miller taken up the question of its adaptation and its construction; and what was even more essential, had not Mr. Thomas Lloyd, then the Chief Engineer of the Royal Dockyard, Woolwich, so early recognised and fostered the invention. To this gentleman the country owes a deep debt of gratitude for the calm, careful manner in which he has encouraged this and all other really useful innovations, and for the warning voice with which he has fearlessly discouraged all wild and improbable schemes, however powerfully patronized.

Between 1846 and 1849 the engines were produced for the 'Blasco de Garry,' the 'Alesta,' the 'Vigilante,' and the 'Pizarro,' for the Spanish royal navy; and in the latter year the engines for the Egyptian frigate, the 'Sharkie,' were built with great success. It should also be stated that a number of engines were likewise constructed for the Austrian Lloyd's packets, which, until the establishment of the Electric Telegraph, brought the earliest Indian news by way of Alexandria and Trieste.

This long and somewhat dry enumeration of engines does not, of course, comprise all the works that were undertaken by Mr. Miller and his partners, nor is it possible within the limits of this sketch to trace the gradual development of the ideas which induced the improvements daily introduced into steam machinery.

Mr. Miller was possessed naturally of an appreciation of beauty of form and of proportion which enabled him to sketch the various parts of a machine almost with the accuracy of a drawing made to a scale, and hence the peculiar aptness of form and fitness of proportion which characterized all his engines. To him is, in a great degree, due the greater use of wrought iron, thus reducing the weight and augmenting the strength of the machines, as well as rendering them more compact, and putting them below the waterline out of the reach of shot. He was a pure mechanic naturally, he had carefully cultivated his tastes by study, and the daily practice of his art completed his qualifications; and if his health had permitted, he would have eventually taken a very high position. Unfortunately his health, which had been for some years very precarious, so failed that, in December of 1852, he was obliged to retire from the firm of which he had been so long the successful chief, and which now still retains its well-earned reputation.

In spite of his painful malady, Mr. Miller, after his retirement from business, continued to cultivate the companionship of artists and literary men, in which he had always taken pleasure; his home was ever open to them, and many brilliant and happy meetings are in the remembrance of his friends, as are also the more social evenings of the Shakespeare Club at an earlier period when many of the now great literary and artistic stars had scarcely reached above the horizon. His taste exhibited itself in the formation of a small but choice collection of pictures, the works of modern artists, all of whom were his personal friends; and these works were his solace: when confined to his chamber, he could look around and, as he expressed it, still fancy that he could hear the well-remembered voices of his friends as he looked upon their works.

He was a Fellow of the Royal Society, and a Member of several other scientific bodies. He was a very old Member of the Institution of Civil Engineers, having been elected in the year 1834. He served for several years as a Member of the Council, and only retired when he was precluded by continued illness from attending the Meetings. That he was devotedly attached to the Institution was shown not only by his taking a vivid interest in all its proceedings up to the period of his last leaving England, but by his munificent legacy to it of Five Thousand Pounds. In recognition of this considerate liberality, the Institution unanimously concurred in the propriety of having a portrait of Mr. Miller suspended in the meeting-room, and establishing a 'Miller Medal,' to be given with the premiums bearing his name.

In spite of the best medical assistance, Mr. Miller's painful attacks of rheumatic gout grew more frequent and acute, and after repeated journeys to warmer climates, he was persuaded to accompany his sister and niece to South Carolina, where he purchased an estate; but he was not allowed to enjoy it for any length of time, as on the 23rd of February, 1860, he expired, after only a few days' illness, in the sixty-third year of his age.

This brief sketch will not permit a detailed account to be given of the progressive labours of a man whose whole energies were fixed on one object, the development of the powers of a machine in which 'he believed,' and to which he saw no limit. Such a believer was Joseph Miller: he was a man of philosophic spirit, and an inquiring mind, with a calm manner and apparently an unruffled temper, withal he possessed untiring energy and indomitable courage and perseverance; but more especially he was remarkable for his rare social qualities. There were few such warm friends as he; and few men have left behind them a name which will so long dwell in the memories of all who had the good fortune to enjoy his friendship.

Mr. THOMAS PENSON, who joined the Institution as an Associate in the year 1839, was an architect in extensive practice, and held for a long period the appointment of County Surveyor for Montgomeryshire. Up to the present time it has not been possible to obtain the materials for his Memoir; but it is hoped that they may eventually be procured for future publication.

Mr. ROBERT BERTHON PRESTON, the representative of the ancient family of Preston, of the Manor of Furness, in Lancashire, was born in Liverpool, on the 25th of June, 1820. At four years of age he lost his Father, who died suddenly whilst travelling with his family. This circumstance produced a grave and lasting effect on the mind of the Son; and tended in some degree to form early in life, a character which was afterwards remarkable for independence of thought, decision, and clear judgment. His education, commenced in England, was chiefly received in Geneva; and his frequent residences abroad, not only taught him foreign languages and acquirements, but enlarged his mind, cultivated his naturally high intellect, refined his artistic taste, and, combined with habits of acute observation, helped to store his memory with varied and useful knowledge. There were few subjects on which he could not give information and advice. His strong practical mind and mathematical talents gave him an early taste for mechanical engineering, which he adopted as a profession, on inheriting from his Grandfather, a large share in the iron and brass foundries and works in Liverpool, which he personally superintended for many years. During his connection with the firm of Messrs. Fawcett, Preston and Co., of which he was the principal partner, the machinery for many first-class steamers was designed and constructed for several British and Foreign Companies; among which may be mentioned the engines for the 'Nubia,' the 'Alma,' the 'Orissa,' the 'Behar,' and the 'Ottawa,' for the Peninsula and Oriental Company,—and the 'Simois,' the 'Jourdain,' the 'Borysthène,' and the 'Méandre,' for the Messageries Impériales of France. The firm was also extensively engaged in the manufacture of sugar machinery, most of the largest cane mills and vacuum apparatus in Cuba, the Mauritius, and the British Colonies, having been constructed at their works. Latterly, their attention was also turned to the manufacture of rifled guns and their appurtenances, the locality offering special advantages for experiments. In all matters relative to business, Mr. Preston, when in Liverpool, took an active part, and his sound practical knowledge and clear views upon all engineering subjects, rendered his advice and opinion, at all times, valuable.

Mr. Preston became a Member of the Institution in 1855; he was also a Member of the British Association, and of the Institution of Mechanical Engineers, at Birmingham.

He was a Member of the Royal Southern and Mersey Yacht Clubs, and the pleasure he took in that pursuit, led him to study shipbuilding, to which he, latterly, paid great attention, and at the period of his decease, he was about commencing experiments on a large scale, with models constructed by himself. He also greatly interested himself in chemical and microscopical studies.

As a patron of art, Mr. Preston was well known. His refined taste, his practised eye, and his just appreciation of talent, caused him to be sought after, alike by artists and connoisseurs of the highest order. Many of the leading artists of the day were among his friends; and the tinted 'Venus,' perhaps the most finished work of Mr. John Gibson, the Sculptor, was executed expressly for him. The collection of works of modern and antique art formed by Mr. Preston, and still carefully maintained by Mrs. Preston, remains as a proof of his liberality and discernment.

At the time when the energy of his talents and character seemed most to promise a career of usefulness, Mr. Preston, like his father, died suddenly at Gloucester, whilst travelling with his wife, on the 9th April, 1860, at only forty years of age, leaving four children, to whom he has bequeathed a name universally honoured and respected; a memory blessed by the numerous recipients of his bounty; and the example of a noble and upright character, firm yet gentle, talented yet modest, devoting an enterprising spirit to the good of his fellow-men.

MR. JOHN GEALE THOMSON was born in Dublin about the year 1816, and in the year 1833, he became a pupil of Sir John Macneill, (M. Inst. C. E.,) by whom he was employed on the works of the Great Holyhead Road. In the year 1838, he was engaged under the late Mr. Brunel, (V.P. Inst. C. E.,) on the Great Western Railway, and he superintended, as Resident Engineer, the construction of the works on that line between Bath and Box, including the Middle Hill Tunnel at the latter place. He was then employed in the same capacity, on the Oxford, Worcester, and Wolverhampton Railway. He was subsequently appointed Chief Acting Engineer of the Dundalk and Enniskillen Railway, a great portion of which line he set out and constructed, and was afterwards engaged, under Mr. Hemans, (M. Inst. C. E.,) in laying out the Dungannon and Omagh Railway, in the north of Ireland. He next proceeded to St. Petersburgh, with Mr. C. E. Austin, (M. Inst. C. E.,) to assist in organising a system of drainage for that city, and then in selecting and laying out a line of railway in the Crimea. It was while thus occupied, that he was seized with illness, under which he rapidly sank. His remains were interred in the cemetery of Perekop, near those of several of his countrymen who fell during the Crimean war.

Mr. Thomson was a man of good abilities, of great industry, and was deservedly esteemed, for the skill and accuracy with which his works were constructed. He was elected an Associate of the Institution in 1834, was transferred to the new class of

Graduates, on its creation in 1838,[1] and became a Member in 1848. In 1844, he contributed a Paper,[2] containing an account of a land-slip which occurred during the construction of the Box Tunnel, for which he was awarded a Walker Premium of Books.

MR. FRANCIS WILLIAM ISHERWOOD WEST, was the only Son of the late Mr. Francis West, of the Honourable East India Company's Service. He was educated at Blackheath, and after serving a regular pupilage under Mr. T. H. Bertram, (M. Inst. C.E.,) at Reading, he was employed by the late Mr. Brunel, for upwards of three years, as an Assistant Engineer, on the construction of the Oxford and Birmingham Railways, and then for one year by Mr. J. R. McClean, (V.P. Inst. C.E.,) on the Birmingham, Wolverhampton, and Dudley Railway. After these lines were opened, he acted for nearly four years, as Resident Engineer on the Wolverhampton division of the Great Western Railway. In September, 1858, he was engaged on the Engineering staff of the East Indian Railway, and on joining, he was appointed Resident Engineer on the Ishangerah division of the line. He continued in the active prosecution of his professional duties in India, until he was prematurely cut off, after a few days' illness, by an attack of cholera, on the 25th of March, 1860, in the twenty-ninth year of his age. He had only been elected a Member of the Institution, on the 7th of February preceding, and he died before the intelligence of his election could reach him.

MR. FRANCIS MORTIMER YOUNG, the only child of Mr. Francis Young, was born in London, in 1814. He was educated by the Rev. W. Tate, at Richmond, Yorkshire, where he attained considerable proficiency in mathematics. In 1831, he became a pupil of Mr. Robert Stephenson, by whom he was first sent for two years to the works at Newcastle-upon-Tyne, to obtain a practical knowledge of mechanics, and then was placed at Coventry, on the London and Birmingham Railway, as assistant to Mr. T. L. Gooch, (M. Inst. C. E.) On the completion of the line, he was appointed one of the Resident Engineers of the Manchester and Leeds, (now the Lancashire and Yorkshire,) Railway, under Messrs. George Stephenson and T. L. Gooch, who were jointly the principal engineers, and he superintended the construction of the difficult works on the Todmorden district. On this section of the line, there were three tunnels, three large viaducts, and two of the largest cast-iron bow-and-string bridges that had, up to that period, been built, besides several heavy rock cuttings and embankments. In 1843–44, he was engaged in making the preliminary sections and surveys for the Leeds and Bradford Valley Line, for which an Act was obtained, after a severe contest in Parliament, in which Mr. Young took part. He was then appointed, by Mr. Robert Stephenson, principal Acting Engineer of that line, and afterwards, under Mr. Gooch, of the extension to Colne, to join the East Lancashire Railway. Mr. Young then determined to turn his attention to the construction of general works, for which purpose he entered into partnership with Mr. Bolton, with whom he successfully executed several contracts in the north of England.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. i. (1838), p. 2.

[2] *Vide ibid.*, vol. iii., p. 129.

Mr. Young became a Member of the Institution, in 1851, but his professional occupations, at so great a distance from London, prevented his taking any active part in the proceedings. He was a man of enlarged and liberal mind, and considerable professional ability, and was always ready and anxious to impart knowledge to others, especially to those associated with him, in carrying out the various works with which he was intrusted.

His death occurred suddenly, in a railway carriage, near Dijon, on the 26th of January, 1860, while returning home from a professional tour in Switzerland. His loss was severely felt by his wife and family, more particularly on account of its suddenness, and the peculiar manner in which it occurred.

CAPTAIN WILLIAM FULLARTON LINDSAY CARNEGIE, R.A., of Spynie and Boysack, was the second Son of Mr. James Lindsay Carnegie, of Boysack, in Forfarshire, and the representative of an ancient Scotch family. The subject of this Memoir was born in Edinburgh, on the 13th of May, 1788. His education was conducted at home, by a private tutor, until his thirteenth year, when he attended public classes in the University of St. Andrews. Having made choice of the army for his future profession, he was placed in a preparatory military academy at Shooter's Hill, near London, whence he proceeded to Woolwich, where, in 1804, he received his commission in the Royal Artillery, after the unusually short probation of six months. He was immediately sent on detachment to the Island of Jamaica, where he remained for three years, and then returned home invalided. After being some time at head-quarters, at Woolwich, he was ordered on active service, and was sent, in 1808, to join the British army in the Peninsula, where he served under the future Duke of Wellington, during the ensuing campaigns, both in

Spain and in Portugal. The War Office regulations precluded him from accepting an appointment on the staff of his relative Sir Thomas Graham, afterwards Lord Lynedoch, and being again ordered to the West Indies, he was despatched to Santa Cruz about the year 1811. He had by this time attained the rank of Captain in the Royal Artillery; and in the year 1814, by the death of his elder Brother, Captain James Lindsay Carnegie, R.N., he succeeded to the family estates, when he assumed the surname of Carnegie, under the tenure by which he inherited the estate of Boysack, he having hitherto been known as Captain Lindsay. In the following year, he returned home, and soon afterwards he left the army, spending several of the succeeding years in foreign travel. In December, 1820, he married Lady Jane Christian Carnegie, daughter of the late Earl of Northesk, and settled on his estates in Forfarshire, where he continued to reside, without any lengthened absence, during the remainder of his long and most useful life.

Captain Carnegie was a man of a vigorous and enlightened mind, and was remarkable alike for his talents and his acquirements. He delighted in scientific pursuits, and he was an energetic promoter of all works of public utility. At the time he settled in the country, he was at an age and in a situation peculiarly favourable for the exercise of his talents, and the manifestation of his public spirit; and the impulses of his example and his energy soon became widely felt. He entered with ardour into agricultural pursuits, devoting his attention to improvements in every branch of farming. He opened pavement quarries on his property of Leysmill and Border, which, by the application of machinery and mechanical contrivances, were worked by him on a considerable scale. It was in the course of these experiments, that a stone-planing machine was invented by Mr. James Hunter, the superintending manager of the quarries, and Captain Carnegie is entitled to the praise of having mainly contributed to bring it into its present perfect state.

Captain Carnegie devoted much time to geological researches, and for many years he annually gave a number of prizes to be competed for by the men employed in his quarries, for specimens of petrifactions and remains discovered in the workings, by which means he was enabled to present to the public collections, many rare specimens illustrative of the geology of the district.

He became an Associate of the Institution of Civil Engineers in 1837; he was also a Member of other scientific bodies, and he was an occasional contributor to their Transactions. He had always taken great interest in the inventions of Mr. George Stephenson, and he had carefully watched the progress of the improvements in the locomotive engine. He was present at the opening of the Liverpool and Manchester Railway, and returning home thoroughly impressed, by what he then witnessed, with the vast importance of the new means of transit, he strenuously exerted himself to introduce it into his own county. He employed, on his own responsibility, the late Mr. Thomas Grainger, to survey a line of railway from the harbour of Arbroath, through the valleys of the Brothock and the Lunan to the county town of Forfar; and ultimately, by his perseverance and influence, a company was formed, and an Act of Parliament was obtained, for the construction of the Arbroath and Forfar Railway. He also took a leading part in promoting the Dundee and Arbroath Railway, to connect those manufacturing and populous towns. These two railways, which were sanctioned by Parliament in 1836, were the first locomotive lines for public traffic north of the Tweed. Captain Carnegie was an active Director of both Companies, and he was the first Chairman of the Arbroath and Forfar Railway Company, which office he continued to hold to the close of his life.

He was a Liberal in politics, and an advocate of the principles of free trade, having in early life devoted much time to the study of the works of Adam Smith, and become impressed with his doctrines upon political economy. In these views, Captain Carnegie stood, for a long series of years, almost alone amongst the landed proprietors in his district, but he lived to see them adopted and carried out by his former opponents. He naturally took an active part in the great anti-corn-law movement, and in the discussions and agitation that preceded the settlement of the question. There have been few men in a private station, who have more completely identified themselves with the discoveries and inventions that have made the last half-century so remarkable in the history of the world. In his own locality, every work of public utility, or that was calculated to promote the local industry and welfare of the population within the sphere of his influence, had his support and encouragement. One of his cherished schemes was the improvement of the sea fishing on the coast, near his residence. He tried anxiously to rouse the hardy race who inhabit the neighbouring fishing villages, to take advantage of the use of trawl boats and nets, a mode of fishing which they never practised, and the neglect of which prevented them, except on rare occasions, from catching turbot and other valuable fish. Although he himself set them an example, his efforts were not followed by the success they deserved. He was so earnest in his purpose, that when on a visit to Kent, in 1846, he endeavoured to prevail upon some of the fishermen at Folkestone, to settle on the Forfarshire coast, and to introduce their mode of trawling.

Captain Carnegie was, for several years, Convener of the County of Forfar, but he retired from that office, when he found his health failing. He was afterwards appointed Vice-Lieutenant for Forfarshire, an office which he held till his death, which took place at his seat of Kinblethmont, on the 13th of March, 1860. A long life, devoted to what he conceived to be the best interests of all with whom he was connected, had insured for him universal esteem and respect.

CAPTAIN EDWARD FRASER, of the Bengal Engineers, Son of a Commander in the Navy of the East India Company, was born in September, 1822. He entered the H. E. I. Company's service in May, 1843, and was appointed to the corps of Sappers. In 1845, he was employed upon the works of the Doab Canal, and in 1846, he received his commission as Lieutenant. In July, 1847, he was appointed Executive Engineer Officer, in charge of the second division of the Ganges Canal. In March, 1851, he returned, on sick leave, to Europe, where he remained till the end of 1853. It was during this period, that he joined the Institution, of which he was elected an Associate in February, 1852. On his return to India, he was employed in the Canal Department of the North Western Provinces, and as Magistrate at Roorkee. In 1855, he became Superintendent of the Northern Division of the Ganges Canal, and in 1856, he was appointed Commandant of the Sappers and Miners. On the breaking out of the Mutiny, he hastened from Roorkee to Meerut, but he shared the fate of many of his brother officers, having been shot by the men under his command, on the 6th of May, 1857.

While engaged on the Ganges Canal, he was placed in positions of great trust, and he served, for a long time, under Colonel Sir Proby Cautley, K.C.B., who described him as "an excellent Engineer, most fertile in resources, and most indefatigable in carrying out his duties"

MR. ROBERT HUGHES was born on the 1st of January, 1800, in Dundee, where he received his education. At the age of fourteen, he was apprenticed to Messrs. James and Charles Carmichael, of Dundee, who at that time, enjoyed considerable reputation as Mechanical Engineers. Soon after the expiration of his apprenticeship, he removed to Lóndon, and worked in the establishment of Mr. Lloyd, of Gravel Lane, whose service he left, to proceed to France, where he obtained employment at the works of Messrs. Manby, Wilson, and Co., at Charenton, near Paris. In 1830, on the breaking out of the French Revolution, he, as well as most of the English workmen in France, was compelled to quit the country. He then returned to Mr. Lloyd, by whom he was soon appointed foreman, in which position he remained till October, 1839, with the exception of a short period, during which he acted as manager for Messrs. Mather, Dixon, and Co., of Liverpool. He finally left the then firm of Messrs. Lloyd and Easter, to become chief foreman of the steam factory then recently established in Woolwich Dockyard, under the direction of Mr. Peter Ewart, the Chief Engineer, who placed great confidence in the knowledge and judgment of Mr. Hughes. He made such good use of the opportunity thus afforded of adding to his professional experience, that on the formation, in April, 1847, of the steam branch, at the Admiralty, he was removed from Woolwich, and appointed Assistant to the Engineer-in-Chief of the Navy, which situation he held until the time of his decease. During this period he aided in carrying out those great improvements which became necessary, in consequence of the application of the screw propeller to the vessels of the Royal Navy, involving, as it did, a complete change in the engines for ships of war.

Mr. Hughes was remarkable for the extreme caution he displayed, before coming to a decision; but when once formed, it was generally so sound, that it very seldom required any modification. He joined the Institution as an Associate in the year 1848, and occasionally attended the Meetings, especially when the subject of steam navigation was under discussion.

He died on the 9th of October, 1860, in the sixty-first year of his age, and was buried in Norwood Cemetery, in the same grave with his wife, who only survived him two days.

Mr. JAMES WARDROP JAMESON, a Son of Mr. William Jameson, Writer to the Signet, was born at Edinburgh, in 1824. He was educated at the High School of that city, and during the years 1841 and 1842, he attended the University classes of natural philosophy, mathematics, and practical chemistry. He appears to have attained proficiency, in each of those subjects, especially in mathematics, for which he gained the chief prize; and he was complimented at the public examination, by Professor Donaldson, as "the clearest-headed scholar who had passed through his hands." From an early period, he showed a decided predilection for mechanical pursuits, and in 1838, he was apprenticed to Mr. James Stirling, (M. Inst. C. E.,) the Engineer of the East Foundry Company, Dundee. At the expiration of his apprenticeship, being desirous of professional improvement and of gaining a practical knowledge of the construction of locomotive engines, he came to England; and in 1844, he was employed in the workshops of the Great Western Railway at Swindon, under Mr. Sturrock; and subsequently, for nearly a year, in the drawing office of the South Western Railway, at Nine Elms, under Mr. John V. Gooch, (M. Inst. C.E.). In the acquisition of engineering knowledge, as in his university studies, he was distinguished for patiently conquering difficulties, instead of endeavouring to evade them; and hence, he soon rendered himself competent to accept offices of a responsible nature. In the latter part of 1845, he became Chief Superintendent of the Locomotive Engine Department of the works of Messrs. Rothwell and Co., Union Foundry, Bolton, with whom he remained for three years, during which time he successfully constructed a number of engines, chiefly for the London and South Western Railway Company. Ambitious of more varied employment, Mr. Jameson joined, in 1848, the engineering establishment of Mr. Philip Taylor, at Genoa. During his stay in Italy, his duties caused him to reside for some time at Milan and at Turin, where his scientific knowledge gained him the esteem of many of the Italian Engineers, and also that of the late Count Cavour. In consequence of Mr. Taylor disposing of his establishment at Genoa, Mr. Jameson left Italy, in 1851, and he was engaged as Assistant Engineer under M. Bourdon, to the Compagnie des Forges et Chantiers de la Méditerranée, at Marseilles, where he remained about three years, occupied chiefly upon the construction of marine engines, and of high-pressure engines for the gunboats of the French Navy. His professional reputation at Marseilles was such, that his services were eagerly sought after, particularly by the managers of the Compagnie de Navigation Mixte, with whom, in 1854, he engaged for four years, as Engineer-in-Chief. He succeeded in overcoming many of the difficulties in which the Company were placed at that time,—in effecting economy,—and in improving the efficiency of their steam fleet, which was of considerable magnitude. In 1858, he voluntarily resigned the appointment, in consequence of the operations of the Company having been affected, by the conclusion of the Russian war and other circumstances, in a manner unsatisfactory to himself; and in spite of tempting proposals to remain, he returned to England.

It was during his residence at Marseilles, that the name of Mr. Jameson became associated with the application of the combined steam and ether engine, for marine purposes. Although this system had previously been experimented upon, in workshops, by the inventor, M. Du Trembley, it was only on its application by Mr. Jameson to several ships of the Compagnie de Navigation Mixte, that it was, for the first time, practically worked out, and proved to be capable of effecting considerable economy of space and fuel. By his skill and experience he was able to overcome successfully the difficulties inherent in the construction of marine engines, combining the use of steam and ether; and although this system has not hitherto obtained extensive application, the results of the careful and numerous trials he made in the steamers of the African and Brazilian Line, cannot fail to be a useful addition to marine engineering knowledge. Mr. Jameson received the Watt Medal of the Institution of Civil Engineers, for his Paper on the performance of the Combined-Vapour Engine,[1] read in 1859, before the Institution.

After leaving Marseilles, he received the appointment of Engineer and Agent of the Oriental Inland Steam Navigation Company of India, whither he proceeded in May, 1859. His attention was first given to the operations of the Company on the Indus, but his stay at Kurrachee being limited to a few months, his labours were confined to the collection of facts relative to the working of the 'steam train' system of navigation, peculiar to the operations of that Company. He then went to Calcutta, in order to establish a 'steam train' on the Ganges. He promptly commenced this undertaking, and the experience he had acquired on the Indus, aided by his thorough knowledge of marine engineering, would, doubtless, have produced important commercial and scientific results, had his health not proved unequal to the heavy professional labours he underwent, in a climate unsuited to his constitution. He died at Calcutta, on the 1st of June, 1860, after a brief illness, adding another to the long list of Englishmen who have fallen in India in the cause of science.

Mr. Jameson's abilities as an Engineer, promised to raise him to an important rank in the profession. He was highly esteemed by all his employers, and he always earned and retained their respect. He was conspicuous for his unimpeachable integrity, and he was always careful, that his conduct should respond to the exalted idea he entertained of his profession, of which he possessed such considerable knowledge, that his opinion might, at all times, be safely relied on. He was devoted to the investigation of principles, but he by no means under-rated the importance of practical knowledge and the study of details. He joined the Institution as an Associate in May, 1859, and if his life had been spared, he would probably have become a very valuable Member of the Society, among whom he had many friends.

MR. WILLIAM SAYCE was brought up as a Land Agent and Surveyor, in which capacity he held a high position at Abergavenny. He was, during several years, in partnership with his Brother, the late Mr. Morris Sayce, at Kington, in Herefordshire, where they carried on a large and lucrative practice; and at that period, he was employed in laying out and in constructing some of the local tramways and turnpike roads of Herefordshire and Radnorshire. During the railway mania of 1845, he was extensively engaged on the preliminary surveys of several projected railways. In 1847, when he joined the Institution as an Associate, he had been in business on his own account for upwards of twenty years, and he was then employed by the Hereford, Newport, and Abergavenny Railway Company, which line he had previously surveyed, to value the property through which it passed. He continued to practise his profession to the period of his decease; but from his constant residence in Wales, he was rarely able to take any active part in the proceedings of the Institution, to the interests of which he was much attached.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xviii., p. 233.

Mr. WILLIAM SIMMS was born on the 7th of December, 1793, at Birmingham, whence he was shortly afterwards brought to London by his parents, by whom he was apprenticed to Mr. Bennett, a mathematical instrument maker of considerable ability and reputation. At the expiration of his apprenticeship, he commenced business on his own account. and shortly afterwards, becoming a Member of the Society of Arts, he made the acquaintance of the late Mr. Bryan Donkin and Mr. Francis Baily, who introduced him to Colonel Colby, the then Director of the Ordnance Survey, for which branch of the public service, he was intrusted with the construction of a great number of theodolites. In 1826, he entered into partnership with the late Mr. Edward Troughton, on whose retirement, at the end of seven years, he became sole proprietor of the business in Fleet Street, which enjoyed such high and deserved reputation, for the accuracy of the instruments manufactured at that establishment.

In 1828, he became an Associate of the Institution, and during many years he was a constant attendant at the meetings. In 1834, he delivered, at the request of the then President, Mr. Telford, a lecture on the Edinburgh Mural Circle, which he had just completed, and upon the subject of Graduating Astronomical Instruments.[1] He constructed instruments for many foreign observatories; and the Royal Observatory at Greenwich contains several specimens of his skilful workmanship, particularly the optical part and the graduation of the transit circle, the altazimuth instrument, &c. The Cambridge mural circle was also constructed by him. He made great improvements in the art of graduating instruments, and by his self-acting circular dividing engine, he reduced the labour of weeks to that of a few hours. He communicated to the Royal Astronomical Society, of which he became a Fellow in 1831, a detailed account of this instrument, (with which the above transit circle, and the zenith sector of the Ordnance Survey were graduated,) which was published in their Memoirs.[1] He took part in the experiments for determining the true imperial standard yard, and also in its construction. In 1852, he was elected a Fellow of the Royal Society.

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[1] *Vide* MS. Minutes of Conversation, Inst. C.E. Also a Paper in Phil. Trans. 1809, p. 105, "On a Method of dividing Astronomical and other Instruments, &c.," by Edward Troughton.

He died at his residence, Carshalton, Surrey, on the 21st of June, 1860, in the sixty-seventh year of his age, highly esteemed for the quiet courtesy and the truthful disposition which he had ever displayed throughout his life.

Mr. ARCHIBALD SLATE was born in East Lothian in 1815, and received his education at the High School, Edinburgh. At about the age of eighteen, he became a pupil at the works of Messrs. Claude Girdwood, and Co., Mechanical Engineers, of Glasgow, of which firm Mr. Charles Atherton, (M. Inst. C.E.,) was at that time the managing partner. Young Slate was so remarkable for his rapid progress in the acquisition of knowledge, and for practical ability in his profession, that he was employed, while still a pupil, in the erection of machinery, in Ireland and elsewhere. On coming to London, he was engaged by Messrs. Bramah and Robinson, of Pimlico. He was, subsequently, intrusted with the management of the Holly Hall Foundry at Dudley, and became the Resident Engineer for the machinery of the mines and furnaces on the estate of Lord Ward, the present Earl of Dudley. On returning to London, he entered the establishment of Messrs. W. Simpson and Co. of Pimlico, and for some time had the management of those works. In 1845, he undertook the erection and organisation of the extensive works of the Birmingham Patent Tube Company, at Smethwick, which he successfully accomplished, and also introduced many improvements into this important branch of manufacture. He then joined the firm of Messrs. Cochrane and Co. of the Woodside Iron Works, Dudley, as partner in the foundry department, of which he assumed the management, and by his labours, contributed essentially to the great improvements that have been there effected, in the manufacture of cast-iron pipes. He was also the originator of several patents, among which was one for the now well-known, and generally used, blast engine, to which his name is attached. He, subsequently, took an active part in establishing Messrs. Cochrane and Co.'s new Iron Works and Foundries, at Middlesborough on Tees. The effective aid afforded by the firm of Cochrane and Co. to the construction of the building for the International Exhibition of 1851 was, in a great degree, due to the energy of Mr. Slate, who was a worthy exponent of the great plans of his friends and partners, Mr. Charles Geach and Mr. A. B Cochrane, (Assoc. Inst. C.E.,) without whose co-operation that building would probably not have been completed in the short period allowed for its erection. After several years of close attention to business, he retired from his connection with that firm, with his health considerably impaired. Unfortunately, he never entirely recovered, and after a long and painful illness he died on the 1st of January, 1860, at the early age of forty-five years.

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[1] *Vide* "Memoirs of the Royal Astronomical Society." Vol. xv., p. 83.

Mr. Slate was one of the founders of the Institution of Mechanical Engineers, of Birmingham, and for some years he was a very constant attendant at the Meetings, and took a prominent part in the proceedings. He joined the Institution of Civil Engineers as an Associate in 1844, and when he was in London he attended the Meetings assiduously, taking part in the discussions with his usual energy whenever the subjects were analogous to his pursuits. He was distinguished by great originality of ideas, at times almost amounting to excess of enthusiasm, but his energy and practical skill enabled him almost to command success, under circumstances that would have appalled other men. He was entirely unselfish in his views and utterly fearless in the expression of his opinions, as was witnessed by the Institution when, at the Annual General Meeting, in 1855, he denounced what he conceived to be wrong, and carried conviction to the minds of all present, for the great good of the Society. He was elected one of the Associate Members of Council for the Session 1858-59, but the impaired state of his health did not permit of his attending to the duties of the office.

He was highly esteemed by a large circle of friends, by whom his long illness and premature decease were deeply deplored.

PREMIUMS AWARDED.

SESSION 1859-60.

THE COUNCIL of the Institution of Civil Engineers have awarded the following Premiums:—

1. A Telford Medal, and a Council Premium of Books, to James John Berkley, M. Inst. C.E., for his Paper, "On Indian Railways, with a Description of the Great Indian Peninsula Railway."
2. A Telford Medal, to Richard Boxall Grantham, M. Inst. C.E., for his Paper, "On Arterial Drainage and Outfalls."
3. A Watt Medal, and the Manby Premium, in Books, to James Atkinson Longridge, M. Inst. C.E., for his Paper, "On the Construction of Artillery, and other Vessels, to resist great internal pressure."
4. A Council Premium of Books, to Edward Leader Willliams, M. Inst. C.E., for his "Account of the Works, recently constructed, upon the River Severn, at the Upper Lode, near Tewkesbury."
5. A Council Premium of Books, to Edward Brainerd Webb, M. Inst. C.E., for his Paper "On the Means of Communication in the Empire of Brazil; chiefly in reference to the Works of the Mangaratiba Serra Road, and to those of the Mauá, the first Brazilian Railway."
6. A Council Premium of Books, to Francis Croughton Stileman, M. Inst. C.E., for his Paper "On the Construction and Enlargement of the Lindal Tunnel, on the Furness Railway."
7. A Council Premium of Books, to James Ralph Walker, M. Inst. C.E., for his "Description of the Netherton Tunnel Branch of the Birmingham Canal."
8. A Council Premium of Books, to Daniel Kinnear Clark, Assoc. Inst. C.E., for his Paper "On Coal-Burning and Feedwater Heating, in Locomotive Engines."

[SUBJECTS

SUBJECTS FOR PREMIUMS.

SESSION 1860-61.

THE COUNCIL invite communications on the following, as well as other Subjects, for Premiums:—

1. A Review of the Plans which have been proposed, at different times, for the Embankment of the River Thames.
2. On the Principles upon which the Works for the Improvement of River Navigation should be conducted, and the effects of the works upon the Drainage and Irrigation of the District; including accounts of the Systems of Moveable Dams, ('Barrages Mobiles') in Rivers on the Continent.
3. On the Effect of Engineering Works in causing injurious Scour, Flooding, or Silting-up, in Tidal Estuaries, or Rivers.
4. On the Effect of Sluicing, in removing and preventing deposits, at the Entrances of Docks on the Coast and in Tidal Rivers.
5. On Reclaiming Land from Seas and Estuaries.
6. On the Results of the Employment of Steam-Tugs on Canals, and of other measures for the Improvement of Canals as a means of conveyance for heavy traffic.
7. On the Methods of constructing Foundations, for large Structures, in deep water.
8. Description of Cast, or Wrought-Iron Cranes, Scaffolding and Machinery, employed in large works, in Stone Quarries, Hoists, or Lifts on Quays, in Warehouses, &c., especially where either Steam, or Water, is used as a motive power.
9. On the Results of Experiments on the Crushing Weights of different materials, particularly as to the Resisting Powers of Rubble Masonry, set in different limes and cements.
10. The Selection of Sites for the Construction of Docks on the course of Tidal Streams, with reference to Communication with Railways and with Inland Navigation.
11. The Selection of Sites for, and the Principles of, the Construction of Breakwaters, Harbours of Refuge, Piers, Moles, (whether solid, or on arches), Sea Walls, and Shore Defences; illustrated by examples of known constructions.
12. The Construction of Lighthouses; their Machinery and Lighting Apparatus; with notices of the Methods in use for distinguishing the different Lights.

13. On the Mechanical Methods of Boring and of Sinking large Shafts, of introducing the Tubbing and the impervious lining, and of traversing running sand, and other difficult strata.
14. The Results of Contrivances for facilitating the Driving of Tunnels, or Drifts in Rock.
15. The Results of a series of Observations on the Flow of Water from the Ground, in any large district; with accurately-recorded Rain-Gauge Registries, in the same locality, for a period of not less than twelve months.
16. On the Construction of Catchwater Reservoirs in Mountain Districts, for the Supply of Towns, or for Manufacturing purposes.
17. Accounts of existing Waterworks; showing the Methods of Supply, the Distribution throughout the Streets of Towns, and the general practical results.
18. The Comparative Duty performed by, and Improvements in the Construction of, modern Pumping Engines for raising Water, for the Supply of Towns, or for the Drainage of Mines; noticing in the latter cases, the depth and length of the underground workings, the height of the surface above the sea, the geological formation, the contiguity of streams, &c.
19. The Results of the use of Bucket and Rotary Pumps, for lifting large quantities of water to a limited height; as at the Haarlem Meer, or at Whittlesea Mere: with descriptions of the Machinery employed, and the application of such machinery to the raising of the Sewage of large Towns.
20. On the Methods in use in various countries for Raising Water for the purposes of Irrigation.
21. The Drainage and Sewerage of Large Towns; exemplified by accounts of the systems at present pursued, with regard to the level and position of the outfall, the form, dimensions and material of the sewers, the prevention of emanations from them, the arrangements for connecting the house drains with the public sewers, and the disposal of the sewage, whether in a liquid form, as irrigation, or in a solid form after deodorisation.
22. On Boiler Inspection as practised in this country and on the Continent, with remarks as to the comparative merits of the two systems.
23. On the most recent Systems of Smoke Prevention, in Stationary, Marine and Locomotive Boilers; and a discussion of the existing difficulties.
24. On the Causes of the alleged Failure in Economising Fuel,

in working Steam expansively, and the probable conditions for insuring success.

25. On the Results of the use of Superheated Steam.
26. On Substitutes for Steam, and the causes of their Failure.
27. On the Results of the use of Tubular Boilers, and of Steam at an increased pressure, for Marine and other Engines, noticing particularly, the difference in weight and in speed, in proportion to the Horse Power and the Tonnage.
28. On the Measure of Resistance to Steam Vessels at high Velocities.
29. The Substitution of Machinery for Manual Labour, for Raising, Lowering, and Reefing the Sails, Weighing the Anchor, &c., on board ship.
30. On Steam Vessels of Light Draught for the Shallow Rivers of India, &c.
31. Description of the 'Great Eastern' Steamer, and of the results of the trial voyages.
32. On the Form and Materials for Floating Batteries and Iron-plated Ships, ('Frégates blindées,') and the points requiring attention in their construction.
33. On the Initial Velocity, Range and Penetration of Rifled Projectiles, and the influence of Atmospheric Resistance.
34. Description of Street Railways and Carriages, as used in the United States of America, in Paris, and at Birkenhead, with the results.
35. On the Ascertained Duration, and other qualities, of the numerous systems of Permanent Way in use in England and in other countries, with their original Cost and expense of Maintenance.
36. Improvements in the Construction of Railway Carriages and Waggons, with a view to the reduction of the gross weight of Passenger and Goods Trains; also of Railway Wheels, Axles, Bearings, Axle Boxes, and Breaks, and of Bearing, Traction, and Buffer Springs; treating particularly, their ascertained duration and their relative friction.
37. Descriptions of the various kinds of Machinery in use in the principal Shipping Ports, for the Shipment of Coal; noticing particularly, those in which the greatest expedition is combined with the least amount of breakage of the coal; and also accounts of the means of unshipping and measuring, or weighing the Coal, on its arrival in Port.
38. On the means of Utilising the products of the Distillation of Coal, so as to make coke commercially as cheap as coal; with Descriptions of the Ovens, and of the best processes used in Great Britain and on the Continent, in the Manufacture of Coke.

39. The Precautions adopted for guarding against Accidents by Fire-damp and After-damp in Mines.
40. The most Effective Arrangement and Form of Centrifugal and Reciprocating Blowing Apparatus.
41. The Chemical Analysis, and the application to economic purposes, of the Gases generated in Iron Blast Furnaces.
42. Description of Modifications of the present systems of Smelting Iron Ores, of Improvements in the Conversion of Cast Iron into the malleable state, and of the Manufacture of Iron generally, comprising the distribution and management of Ironworks.
43. Improvements in the Manufacture of Iron for Rails and Wheel Tyres, having special reference to the increased capability of resisting lamination and abrasion; and accounts of the Machinery required for rolling heavy Rails, Shafts, and Bars of Iron of large sectional area.
44. On the use of Steel Bars and Plates in Enginework and Machinery, for Boilers and for Ship Building.
45. The Process of Manufacture, and mode of treatment, of Aluminium.
46. On the Importance of Balancing the Rotating, or Alternating parts of Machinery.
47. On the Forms and Dimensions of Journals of Machine Shafts, Axles, &c.; with the best Composition for the linings of Bearings, and the most approved methods of Lubricating.
48. On the Mechanism of Astronomical Instruments.
49. On Machinery adapted for the Better Separation of the various Substances found in Combination with Metallic Productions.
50. On the Substitution of Machinery for Manual Labour in Mining Operations; and on Hydraulic Machinery in Mines.
51. On the Improvements which may be effected in the Buildings, Machinery, and Apparatus for producing Sugar from the Cane in the Plantations and Sugarworks of the British Colonies, and the comparison with Beet Root, with regard to quantity, quality, and economy of manufacture.
52. Accounts of the Improved Systems of Storing, Cleansing, and Drying Corn, and of producing Flour.
53. Description of the Machinery adapted for the Preparation of Indian Corn.
54. Improvements in Flax Machinery, and in the processes for preparing the Flax for manipulation.
55. The uses of Vulcanised, or Mineralised Caoutchouc; the means of increasing its durability, and the modes of causing its adhesion to metal.

56. On the Application of Photography to Engineering.
57. The Construction of Clocks to be moved simultaneously by the agency of Galvanic Electricity.
58. On the Form and Construction of Submarine Telegraph Cables, most suitable for certain specified depths; and an investigation into the nature of any new substances adapted for the insulating medium.
59. On the Application of the Electric Telegraph to Railway Train Signalling.
60. Memoirs and accounts of the Works and Inventions of any of the following Engineers:—Sir Hugh Middleton, Arthur Woolf, Jonathan Hornblower, Richard Trevithick, William Murdoch (of Soho), Alexander Nimmo, and John Rennie.

Original Papers, Reports, or Designs, of these, or other eminent individuals, are particularly valuable for the Library of the Institution.

The communications must be forwarded, on or before the 28th of February, 1861, to the house of the Institution, No. 25, Great George Street, Westminster, S.W., where copies of this paper, and any further information may be obtained.

CHARLES MANBY, *Honorary Secretary.*
JAMES FORREST, *Secretary.*

25, *Great George Street*, *Westminster*, *S. W.*,
October, 1860.

NOTICE.

It has frequently occurred, that in Papers which have been considered deserving of being read and published, and have even had Premiums awarded to them, the Authors may have advanced somewhat doubtful theories, or may have arrived at conclusions at variance with received opinions. The Council would, therefore, emphatically repeat, that the Institution must not, as a body, be considered responsible for the facts and opinions advanced in the Papers, or in the consequent Discussions; and it must be understood, that such Papers may have Medals and Premiums awarded to them, on account of the Science, Talent, or Industry displayed in the consideration of the subject, and for the good which may be expected to result from the discussion and the inquiry; but that such notice, or award, must not be considered as any expression of opinion, on the part of the Institution, of the correctness of any of the views entertained by the Authors of the Papers.

EXTRACTS FROM THE MINUTES OF COUNCIL, FEB. 23rd, 1835.

"The principal Subjects for which Premiums will be given are:—

"1st. Descriptions, accompanied by Plans and explanatory Drawings, of any work in Civil Engineering, as far as absolutely executed, and which shall contain authentic details of the progress of the work. (Smeaton's Account of the Edystone Lighthouse may be taken as an example.)

"2ndly. Models, or Drawings, with descriptions of useful Engines and Machines; Plans of Harbours, Bridges, Roads, Rivers, Canals, Mines, &c.; Surveys and Sections of Districts of Country.

"3rdly. Practical Essays on subjects connected with Civil Engineering, such as Geology, Mineralogy, Chemistry, Physics, Mechanic Arts, Statistics, Agriculture, &c.; together with Models, Drawings, or Descriptions of any new and useful Apparatus, or Instruments applicable to the purposes of Engineering, or Surveying."

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JOSEPH LOCKE, M.P., F.R.S.

HONORARY COUNSEL.

CHARLES F. F. WORDSWORTH.

HONORARY SOLICITOR.

WILLIAM TOOKE, F.R.S.

HONORARY ARCHITECT.

THOMAS HENRY WYATT, F.R.I.B.A.

January 8 and 15, 1861.

GEORGE PARKER BIDDER, President, in the Chair.

The discussion upon the Paper, No. 1,030 "On the Maintenance and Durability of Submarine Cables in Shallow Waters," by Mr. W. H. Preece, was continued throughout these evenings, to the exclusion of any other subject.

At the Meeting of January 8, the following Candidates were balloted for and duly elected:—Henry Byrne, Mark William Carr, Edward Garlick, Robert Hodgson, Benjamin Piercy, and Samuel Barton Worthington, as Members; Captain George Baillie, B.A., Joseph Hancox, and Charles William Scott, as Associates.

January 22, 1861.

GEORGE PARKER BIDDER, President, in the Chair.

No. 1,023.—"On the Rise and Fall of the River Wandle; its Springs, Tributaries, and Pollution."[1] By Frederick Braithwaite, M. Inst. C.E.

This account is compiled from a careful survey, made early in the spring of the year 1853, of the River Wandle from its rise at Carshalton, 111 feet 2 inches, and at Croydon, 123 feet 10 inches above Trinity high-water mark, to its outfall in the Thames, at Wandsworth. In the course of the survey, special notes were taken of the several springs, tributaries, and of the sewage from drains, which contributed to swell the amount of the water. Levels of the successive falls of the river, from its spring heads, through the mills, were carefully taken; and a complete set of gaugings of the water from the numerous springs and tributaries, flowing into the river.

The branch of the River Wandle rising at Carshalton, is supplied from three principal springs, the highest of which, issuing from the chalk, in Carshalton Park, is called the 'Grotto Spring Pond,' and is 105 feet 10½ inches above Trinity high-water mark. The next in elevation is the 'Hogs' Pit Pond,' which is situated in the same park, and is 111 feet 2 inches above T.H.W.M. The third spring rises in the grounds of the Ordnance School, and is 109 feet 3¼ inches above T.H.W.M. The two latter springs unite at the Carshalton town ponds, and thence descend through the mills, except a portion of the Hogs' Pit Pond, which, with the whole of the water from the Grotto Spring, and from other underground sources, forms a separate mill stream.

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[1] The discussion upon this Paper occupied portions of four evenings, but an abstract of the whole is given consecutively.

The head of water at the lake in the grounds attached to the Ordnance School, varies 4 inches, or 5 inches, according to the rainfall; and when the lake is emptied, it is refilled from the springs, in thirty hours. Besides the principal head from the west side, there are numerous springs in the bottom. A drain from the kitchen of the school discharges into the lake; to insure the purity of the water, a special pipe is, therefore, laid into the head, for some distance, leading thence to the cistern on the tower.

Mr. Sawyer's mill, which is used for grinding flour, is the first mill on this branch, and it is 104 feet 9 inches above T.H.W.M. The stream, as before mentioned, comes from Carshalton Park, and it is sufficient to drive a wheel of 7 H.P.

The town ponds are supplied from several sources: first, the Ordnance School water, flowing through a barrel culvert at the north-west end of the upper pond; secondly, a spring issuing from a pipe into a pond in Waterhouse Lane, and thence running by a barrel culvert into the upper town pond, about the middle of the west end;[1] thirdly, the large supply from Mr. Sawyer's mill, out of Carshalton Park; and fourthly, the town ponds, which abound in springs. Into these ponds there is drainage, first from houses and privies at the west end; secondly, from a garden and bath house at the north end; thirdly, from three gratings in the roads, and also a cattle trough; and fourthly, from a garden at the east end. The level of the water is 107 feet 4¾ inches above T.H.W.M. The collected waters pass under an ornamental bridge, into Mr. Cressingham's grounds, where a large drain, or sewer, empties itself into the river from the dwelling house. At Mr. Charrington's, the water turns a flour mill of 24 H.P., the waste sluice being alongside the wheel, in the mill; the head waste-weir, or overfall, is situated at the east side of the mill. The privy and the drains from the house, empty themselves into the mill tail. The mill below belongs to Mr. Muggeridge, and is used for the manufacture of paper. It has a wheel of 15 H.P., and a steam engine of 12 H.P., and it is 104 feet 9 inches above T.H.W.M. The water at this place is much polluted, by rag-washing and bleaching, in addition to the strong alkaline solution employed by the manufacturers. The quantity of water taken from the Wandle, as estimated by the two pumps supplying the rag tanks, amounts to 108,000 gallons daily. At the back of the mill is a boggy, wooded piece of land, which receives the water from the overfall from

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[1] The gauging under the head 'Ordnance Pond,' in Table, page 196, includes both the above sources.

Mr. Charrington's mill, from the waste sluice from Mr. Hedgecock's snuff mill, and from the land drainage of the eastern side of the river, which is steep. Here the waste water, coming across the meadows, from Carshalton Park, joins the main stream, over the overshot wheel of 9 H.P. of Mr. Hedgecock's snuff mill; in addition to the wheel, there is a steam engine of 8 H.P. The level of the mill head is 99 feet 9 inches above T.H.W.M. Lower down is Mr. Ansell's snuff mill, driven by two wheels equal to 16 H.P., and Mr. Ashby's flour mill, of 16 H.P.; the mill head being common to both, and at 83 feet 1½ inch above T.H.W.M. The Carshalton water-compensation main enters this head, which has waste sluices, but no overfall. The mill tail is divided into two streams. At the eastern (Mr. Ashby's) end, or bridge, the road drains into the streams, and a pipe 9 inches in diameter, introduces the meadow water. The streams rejoin lower down, where a small draining wheel is placed, worked by Mr. Ashby's stream, to withdraw the land water from the adjoining meadows, into the river. The road running along the river bank drains into it, and after bending away from the river side, drains collect the land water on both sides, as well as the water from the houses, and finally discharge themselves, one above, and the other below Hack Bridge, into the Wandle, with an auxiliary drain also below the bridge. At a short distance below the draining wheel, the river unites with the Croydon branch, at the mill head of the oil and felt mills, now unoccupied.

The general character of the water of this branch is remarkably brilliant and pure, with the exception of the water from the paper mills above mentioned, and where the road drainage is discharged into it, after heavy rains, which impurities, however, quickly subside. The water contains a small quantity of sulphate of lime, and is of about 16° of hardness.

In the Croydon branch of the River Wandle, the principal flow of water is derived from a stream called the Bourne, which rises about 8 miles south of Croydon, in Marden Park, in the parish of Woldingham. About two miles from Croydon on the Brighton road, two other streams rising from ponds on the right-hand side, are united with it, and the joint streams enter Croydon by a culvert, nearly a mile in length. In rainy seasons, the drainage of the roads and of the surface south of Croydon, passes into the same channel; but at other times, the water is very clear. The supply from the Bourne is very precarious, flowing only once in five, or seven years, whenever the rainfall is excessive, and then only for a limited period. When the springs at Marden Park have flowed about thirty days, in the direction of Croydon, they commence flowing in the direction of West Wickham, in Kent, about four and a half miles from Croydon. There is, however, evidence, that the Bourne ran during two entire years, in 1841 and 1842, a period of great rain. In the garden of Blunt House, Croydon, there is a spring from which, formerly, issued a considerable supply of water; but the level is now usually below the grating, constructed to convey it to the channel of the Bourne. In 1853, when there was a depth of water of about 6 feet, in the garden pond, only a small quantity flowed away. A considerable spring existed in the garden of Mr. Chatfield, at Croydon, but this has now failed, owing to the various cuttings for the sewerage, and for the water pipes now laid down by the Local Board of Health. The water from the Bourne, when it flows, enters an open course at the bottom of the yard of Mr. Harris, the builder, near Croydon.

Another important spring, which is 132 feet 2 inches above T.H.W.M., rises in Croydon in the garden of Mr. Overton, brewer and maltster; there are also numerous springs, over an area of about 400 yards round his premises, including one in the malthouse, and another at the steam mill gates, which together enter into what remains of Land's Ponds. There is also a spring in the yard of Mr. Potter, the fellmonger, which gives a good flow of water, and after being used on the premises, falls into Land's Ponds. From this last site, the collected waters flow into the Bourne Brook, at Mr. Harris's yard, being there joined by a supply from another small spring, issuing from the works of Mr. Edwards, the tanner, in Church Street, by a small open sewer, running from the north, draining the adjacent roads and houses, and by a gentle spring of pure water, (the remains of Scarbrook Pond, now filled up,) which passes through Mr. Harris's yard. This water from Land's Ponds, together with other polluted water, amounts to 1,458,000 gallons per day. After leaving Mr. Harris's yard, where all the Croydon streams unite to form the eastern branch of the Wandle, 123 feet 10 inches above T.H.W.M., and flowing at the rate of more than 19,000,000 gallons, every twenty-four hours, it passes under the Croydon and Epsom Railway, receiving the drainage of that line, and then leaving the filter house, on the north, runs westward towards the Waddon mill.

The first mill on the Croydon branch is in the occupation of Mr. Chasemore, at Waddon, and is used for grinding corn, the water power being one wheel of 25 H.P. The mill head is 116 feet 9½ inches above T.H.W.M., and it is supplied, partly from the polluted stream descending from Croydon, already described, and partly from a large pond full of springs, bounded on the south by Waddon Court farm; the openings at the mill head and the land drainage together, producing upwards of 1,200,000 gallons per day, independent of the Croydon supply. At the north end of the mill pond is the waste sluice, and also a small overfall, over which there is a considerable flow of water. This mill has occasionally to stop in dry seasons, one-quarter of its time, for want of water.

The next mill, in the occupation of Mr. Lambert, is 105 feet 7 inches above T.H.W.M. The mill head, like that at Waddon, is full of mud; at times, the water does not exceed 4 inches in depth, and the stench is only kept in check, by a low temparature. The chief cause of this, is the filth from Croydon, which finds its way through the wheel at Waddon mill. It is seven years since the head was cleared, but the greater part of the deposit has accumulated recently. Waddon mill waste does not entirely flow into this mill head, as a branch enters below the tail, beyond Beddington Ford. Mr. Lambert's mill employs two wheels, equal to 25 H.P., for grinding snuff. There is an outfall at the mill head on the north side, as well as a waste sluice at the top of the garden, which joins the Waddon waste, into which also enters the drainage of the northern lands. At the south side of Beddington Ford, there are several small springs, of which three are conspicuous. One issues immediately below the mill tail at Mr. Lambert's mill; a second from a culvert under the wall of a garden, by the foot bridge; and the third from a small pond in a meadow, westward of the ford. Two roads here descend to the water, bringing with them the south upland drainage. There are also five other drains on the south side, two of which, obviously proceed from houses. The head of a culvert is likewise seen, nearly in mid-stream, choked up, but apparently, full of filth. Below the ford, on the south side, a small sluice conducts a portion of the river into the gardens of Beddington House, under which it passes, through a culvert, into a large ornamental pond opposite the west front, 86 feet ¾ inch above T.H.W.M. The main stream flows through some plantations and ornamental grounds over cascades, and enters the park to the north of Beddington House, where it is joined by a branch from Waddon waste. The river, in its course through Beddington Park, again receives the water from the before-mentioned pond. The houses along the south of Beddington House gardens, have a small drain directed to the Wandle. There were no springs observed in the park, but a considerable quantity of land-drainage water collected into one great drain, which discharged into the river at the west end of the park, and being traced to its branches, was found to consist, partly of the waste water of the river derived from Beddington Park, partly of land drainage from all the uplands north of the park, and partly of the leakage from the pervious bed of the river. Another smaller drain at the west end, enters the road from Mitcham to Wallington, running by its side and discharging into the river, above Wallington Bridge. Another land drain issuing from the inclosure of the park also flows, increasing in its course, towards Beddington Corner, where it enters the Wandle, joined with other streams.

Above Wallington Bridge there is a corn mill, belonging to Mr. Holloway, driven by one wheel of 12 H.P., the head being 82 feet 2½ inches above T.H.W.M. There is an overfall above the mill, into the tail of which the adjoining land drains, and it also receives the waste water from Beddington Park, in cases of overflow. These works consume about 40,000 gallons of water daily, which, after being used for washing the dirt from the flock, is returned into the river. On the south side of the corn-mill tail, there is a spring from a pond in Mr. Bridge's park, flowing into the river over a cascade; also another flowing from the same direction, entering through a small culvert. On the south-west side of Wallington Bridge, there is a spring rising from a pond, about a quarter of a mile towards Carshalton, bringing with it the road drainage. The land below Wallington on the south side, is high, and drains directly into the river, while that on the north, drains into the waste water below the oil and felt mills.

Above Hack Bridge there are three works: first, an oil mill, having one wheel of 16 H.P.; secondly, a felting mill, occupied by Mr. Mears, using one wheel of 16 H.P., where a large quantity of water is soiled in felting, washing, and dyeing; and, thirdly, skin works. There is no overfall at these mills, but two large sluices regulate and discharge the surplus. At the mill head the junction is formed with the Carshalton branch, the united streams passing northward under Hack Bridge. The level of the water at this junction, is 75 feet 1¾ inch above T.H.W.H.

The following Table gives a summary of all the gaugings, south of Hack Bridge:—

	1st Average. Gallons per day.	2nd Average. Gallons per day.
CARSHALTON BRANCH.		
1. Grotto Spring Pond . . .	3,550,410	3,377,250
2. Hogs' Pit Pond, &c. . . .	1,955,160	2,233,260
3. Ordnance, or Upper Town Pond .	7,740,450	7,100,100
4. Mr. Sawyer's Mill head . .	4,663,890	4,413,870
	17,909,910	17,124,480
CROYDON BRANCH.		
5. Bourne Brook	17,625,600	16,158,780
6. Land's Ponds, &c.	..	1,458,000
7. Croydon Sewage[1] . . .	3,621,170	2,192,400
Waddon Springs and Drainage .	..	1,243,440
8. Waddon Mill head . . .	21,246,770	21,052,620

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[1] Since these gaugings were taken, the Croydon Sewage Outfall has been removed to Beddington Corner, below Hack Bridge.—EDITOR.

Croydon Branch—*continued.*	1st Average. Gallons per day.	2nd Average. Gallons per day.
Waters from Carshalton	17,909,910	17,124,480
Ditto from Croydon	21,246,770	21,052,620
Ditto from several parts, viz.—		
Town Ponds, Carshalton Drainage, Carshalton to Hack Bridge Beddington Ford Drainage of Beddington Park Springs and Drainage at Wallington Bridge Springs and Drainage, generally	24,331,840	14,573,880
9. River Wandle at the union of the streams above Hack Bridge	63,488,520	52,750,980
or, cubic feet per minute	7,054	5,861

The following Table exhibits an estimate of the amount of sewage water which, if collected, would daily flow down a main pipe at Hack Bridge, during heavy rains:—

Croydon.	Gallons per day.	Gallons per day.
Sewage from Houses	120,000	
Bleaching mills	280,000	
Flushing water	200,000	
Rain water	1,592,400	2,192,400
Land's Ponds, gauging No. 6.	..	1,458,000
Storm water at Croydon and neighbourhood, on 320 acres, at 1 inch of rain-fall, or ½ gallon per square foot, one-half of which drains by the surface	3,484,800	
Less by rain already estimated	1,592,400	1,892,400
Croydon to Hack Bridge.		
Flock Mill	40,000	
Felting Mill, say	20,000	
Sewage from 77 Houses, at 50 gallons each	3,850	
Carshalton to Hack Bridge.		
Mr. Muggeridge's Paper Mill	108,000	
Sewage from 186 Houses, at 50 gallons each	9,300	
Ditto towards Wallington, 234 Houses at 50 gallons each	11,700	192,850
Drainage of Roads, 8 miles, 20 feet wide, 1 inch depth of rain, or ½ gallon per square foot		442,400
Field Drainage into Roads, 4 acres per mile		696,960
Filtration into Sewers, 5 miles, 180 cubic feet per mile		620,000
Total Drainage at Hack Bridge during heavy rains		7,495,010
or, cubic feet per minute		833

The stream below Hack Bridge divides itself, and surrounds Mr. Gurney's property. The middle stream leads to Mr. Darling's Mill; the eastern portion runs to waste over a tumbling bay, and thence over two others, entering the river again in Mr. Reynolds's grounds. All the land east of the river to this point, is drained along the private road to Mr. Gurney's, by ditches which fall into this waste water. It may be generally remarked, that the land on the Carshalton, or west side, for a considerable distance upland, drains, without interception, into the Wandle, as far down as Mitcham Bridge. After the junction of the waters at Mr. Reynolds's, a brook on the Carshalton side from Sutton, falls into the river, bringing with it the sewage from several houses. Above Hack Bridge, the soil consists of a mixture of chalk and gravel; but below the bridge it is wholly of gravel, or sand, though there is clay close under it, as a clay pit may be seen at the bend of the river before Mr. Reynolds's house. Mr. Darling's mill for grinding corn is driven by one wheel of 20 H.P. The head is 67 feet 2 inches above T.H.W.M. The following are the average gaugings of the mill stream and waste water:—

No. 10. Waste water at Hack Bridge.

	Gallons per day.
No. 1. . . .	32,956,720, or 3,662 cubic feet per minute.
„ 2. . . .	29,762,550
„ 3. . . .	25,763,100
„ 4. . . .	21,625,290, or 2,403 cubic feet per minute.

No. 11. Mill stream.

17,000,550.

Proceeding along the river to Beddington Corner, there are several mills and works established on the stream and adjacent to it; Mr. Bourne's corn mill, using one water wheel equal to 14 H.P., Mr. Atkins' dye and drug mill, employing a wheel equal to 12 H.P., Mr. M'Crae's leather mills, using two wheels equal to 16 H.P.; (the head of these mills is 64 feet 2 inches above T.H.W.M.); Mr. Davison's print works, and a large tan yard belonging to Mr. M'Crae, where there is a waste sluice and an overfall at the mill head. The waste water passes at the back of the washing-houses and pits, and is joined by the tail water of the small wheel. A great deal of filth is constantly being discharged from these works, generally polluting half the stream, with the washing of the skins, and with lime and other impurities. At least 20,000 gallons of water are used daily, and a considerable quantity of chloride of lime. A drain pipe, 4 inches in diameter, would be sufficient to carry off the water, but a settling pond must be provided for the chloride of lime. The influence of the taint from these works was perceptible for a considerable distance down the stream, and pieces of skin were also observed floating on the surface. Mr. M'Crae's tan yard drains into a waste from the river below the works, on the west side, and introduces into it lime and other impurities, suspended in a large quantity of water, (30,000 gallons at least,) which is eventually discharged into the river. Again, at Mr. Searle's mill tail, half a mile below the tan yard, flocculent matters are frequently seen in the water, and the annoyance has even been complained of, at Mitcham Bridge. A drain from the roads west of the river, falls into the waste at the same place as Mr. M'Crae's drain. At Mr. Davison's print works, the silk goods are principally rinsed in the river, and a large quantity of water is essential for this purpose; 23 cwt. of sulphuric acid, 13 cwt. of alum, 24 gallons of muriate of tin, with chloride of lime, prussiate of potash, nitrate of iron, sulphate of copper, and oxalic acid, were used in these works, and discharged into the Wandle, every week.

On the east side of the river, lies Mitcham Common, which is gravelly, and generally well charged with water; so that there would be considerable difficulty in cutting a trench, or making a sewer, on account of the water which would flow in, or filter through the joints of the works. On the sides, a small drain from under a culvert, enters the river, where the stream parts, to circulate round an osier bed. At the most easterly part of this separation, the drainage water of the swampy land around it enters, as well as, at times, a considerable stream which is brought from a culvert, about 3 feet in span, under the main road. This stream, on being traced higher up, is found to be composed, partly of water from the Wandle, flowing from Mr. Reynolds's land, through watercress beds, into the common under the road, partly from the drainage from Croydon and Mitcham Commons, partly from the high road drainage, and partly from the land drainage in Beddington Park. The gauging of the above stream averages 4,172,760 gallons, every twenty-four hours. Two small culverts pass under the ground, into the broad ditches to the north of the osier bed, with a fall of about 18 inches, which, with the drainage of the adjacent lands, supplies the mill head of Mr. Arney's gelatine works. Following the river, the bottom is observed to be very muddy for some distance.

The next mill on the stream is Mr. Sprule's dye wood and drug mill, employing two wheels equal to 30 H.P., and between the wheels is the waste sluice. The head is about 58 feet above T.H.W.M. To the westward is Mr. Searle's corn mill, driven by one wheel of 28 H.P.; there are two cottages at the mill tail, with privies overhanging the stream. Mr. Sprule mentions, that in 1852, being short of water for some time, the gates were shut down three hours in every twelve hours, and even then, there was a deficiency of water. The water at these mill heads was not clear.

To the east of Mr. Sprule's mill, towards Mitcham Common, are the gelatine works of Mr. Arney, using one wheel of 6 H.P. The mill head is 56 feet 2½ inches above T.H.W.M. The wheel is driven by water from Beddington Corner, and the tail water keeping alongside of the Wandle, enters it over a cascade below Mitcham Bridge, out of a culvert in the grounds of Mr. Bidder, (President Inst. C.E.,) where the stream divides to supply the mill of Messrs. Dempsey and Hind. Adjoining Mr. Arney's are the small print works of Mr. Downing; the consumption of chemicals is but little. A pipe, 6 inches in diameter, would serve to drain the refuse of both the above works. The waste water from Mr. M'Crae's tan yard, joins at Mr. Searle's mill tail, on the main stream; the clay bottom of the river begins then to be seen, and continues to Mitcham Bridge mills. The water along this bottom is not clear, and is spoken of by the inhabitants of the neighbourhood as unfit to drink, having a chalybeate taste, like spa water; the well water of private houses is much preferred. At the bend below the above mills, a small brook on the west side runs into the river. On the north-west side of the river, some new ditches in the meadows were strongly impregnated with oxide of iron; these drain into the river below Mitcham Bridge. At the bar above the mills at Mitcham Bridge, a small waste branch leaves the river, proceeding through very swampy ground, and empties itself, through a sluice, into the tail of the felt mills. To the south of Mitcham Bridge are situated the following mills: Mr. Jones's felt mills, the head being 53 feet 2 inches above T.H.W.M., using one wheel of 23 H.P.; Mr. Glover's corn mill, having one wheel of 24 H.P.; and Mr. Ashby's corn mills, using one wheel of 20 H.P. At the felt mills, only a small quantity of soap and dye is discharged into the river. At the mill head, there is an overfall and waste sluice, leading by the back of the felt mills, and then joining with the mill tail, it passes along to form the head for the small snuff mill, and flowing thence through a sluice, joins the mill stream near the bridge. A small sewer discharges into the river east of the bridge, and a barrel drain also discharges part of the tail water of Mr. Arney's mill.

Below Mitcham Bridge the river divides itself into two streams, the western branch proceeding to Mr. Rutter's snuff mill, at Ravensbury, the eastern branch to Messrs. Dempsey and Hind's print works, serving in its course, through Mr. Gifford's grounds, for an ornamental water, in which trout is very abundant. Below Mr. Gifford's grounds, are the print works of Messrs. Dempsey and Hind, which employ one wheel of 8 H.P.; the mill head is 46 feet 7 inches above T.H.W.M. This firm used half a carboy of sulphuric acid weekly; a carboy, or about 8 gallons, of muriate of tin per month; and 5 cwt. of prussiate of potash, and 5 cwt. of oxalic acid per annum; also a certain quantity of sulphate of copper, nitrate of iron, chloride of lime, &c., all of which materials are discharged into the river. Moreover, the works require, for washing the goods, all the water that can be obtained, and four men are constantly employed in rinsing them in the stream. The deep colouring matter may be observed for more than 200 yards. Immediately below Messrs. Dempsey and Hind's mill, are Mr. Rutter's snuff mills, at Ravensbury, employing two wheels equal to 21 H.P. The head is 47 feet above T.H.W.M. At Mr. Rutter's mill head, there is an overfall into Messrs. Dempsey and Hind's mill head, and an overfall from the latter leading to his mill tail, which joins the main stream below Ravensbury Bridge. On the west side of the stream, a small cut enters some ornamental grounds, re-entering the Wandle a little distance above Mr. Hatfield's mill. A small drain, by the side of the road at Ravensbury, leading from some adjacent lands, runs into the cut. Lower down the stream is Mr. Hatfield's snuff mill, employing two wheels equal to 20 H.P; the head water is 41 feet 7 inches above T.H.W.M. The mill head has an overfall at each side; the eastern is directed into the tail of the mill just above where the river divides, and the western, after circulating through the ornamental grounds, enters the west branch of the Wandle, which also receives the land drainage. The eastern stream is embanked, till it reaches Messrs. Welch and Margetson's print works, at Phipp's Bridge, where the mill head is 36 feet 9¾ inches above T.H.W.M. At these works considerable quantities of water are used, in rinsing and washing the goods; in short, the whole of the eastern division of the river is required. The mill head has a regulating sluice, and another waste on the eastern side, which, after passing through some ornamental grounds, enters the stream called the Pickle. The western stream re-enters at the mill tail of these works, at Phipp's Bridge, where also a small tributary empties itself. The small water-wheel required for these works is of 8 H.P. Messrs. Welch and Margetson used weekly, about three carboys, or 6 cwt., of sulphuric acid, ½ ton of alum, three carboys of muriate of tin, besides small quantities of other chemicals. For the supply of water to the vats, a pump is constantly at work which raises about 6,000 gallons daily, all of which is contaminated and is discharged into the eastern waste water. Besides this, there is an absolute necessity for a large supply of water in the washing process, for without it, the excess of dye washed out of the printed part of the fabric, would spoil the plain part.

A short distance below the above works, the Pickle takes an easterly direction. This is a dirty stream, receiving sewage, and the refuse water from Messrs. Welch and Margetson's works, at Phipp's Bridge, and from Messrs. Littler's, and Mr. Welch's, at Merton. There is a drain, 3 feet in span, running along the Mitcham Road, from a medical distillery, the water in which is, occasionally, much tainted with peppermint, lavender, and other herbs. It also brings sewage from Mitcham, and eventually, it joins the Pickle. Two field drains run into the same stream on the east side. A small overflow from the stream, passes under the Merton Road, and joins the waste water at Messrs. Child's mill head.

Returning to the river, Messrs. Littler's print works at Merton Abbey, are the next which present themselves, employing two wheels equal to 15 H.P., the level of the water being 34 feet 10 inches above T.H.W.M. The waste water from the works flows into the Pickle, and the mill tail joins that of the Abbey works, to form one stream above Mr. Welch's, at Merton. At the Abbey works, there is only one regulating sluice, the head being 32 feet 4½ inches above T.H.W.M. At Messrs. Littler's, in dry seasons, there is not sufficient water in the whole river, for washing purposes; twenty men are constantly employed in rinsing dyed goods. Six and a half carboys, or 13 cwt. of sulphuric acid, and 3 cwt. of alum are used weekly, as mordants, and though all, or nearly all, the alumina is struck into the material, yet the equivalents of sulphuric acid and potash of the alum are washed out, and are, at present, discharged into the stream. Prussiate of potash, muriate of tin, chloride of lime, and nitrate of iron, are also used, but not in large quantities, and a great proportion of these also pass into the stream by the washing process. The works require a constant flow, through a pipe 5 inches in diameter, for the use of the vats, baths, &c., and this water runs off extremely foul.

On the south side of Merton Bridge are Mr. Welch's print works, which employ a wheel of 8 H.P.; the head is 32 feet 4½ inches above T.H.W.M. An overfall from the main stream supplies the mill head, which is a large basin. There is a rinsing-wheel worked by the mill power fixed in the main stream, and ten men are constantly employed in rinsing the goods. They would require a stream 4 feet wide and 3 feet deep, including the present machine in the river, for washing purposes. The mill tail passes behind Messrs. Shears and Sons' copper works.

It may be generally remarked, that the water below all the print works was much coloured, when any print-washing was going on. The colour did not appear to settle, it only became largely diffused. The water used for cleaning the blocks is also sent into the river. In clear weather, the contrast between the water at the Carshalton springs, and that at Merton Bridge, was very marked; proving to the sight alone, how unfit the water had become for drinking purposes, during its progress, receiving the impurities of so many works, and the drainage from such a soil; in dry seasons, this must be still more striking.

Immediately adjoining Mr. Welch's, are the copper works of Messrs. Shears and Sons, employing three wheels, collectively equal to 50 H.P.; the mill head is 33 feet 1½ inch above T.H.W.M. This mill works day and night, and being not unfrequently short of water, there is an additional steam engine equal to 40 H.P. At the mill head, an overflow on the east side, conducts the waste water into Mr. Welch's mill tail, and thence joins the main stream at Merton Bridge. The mill tail of the copper works, and also the Pickle enter at the same place, forming one united flow of water, under Merton Bridge. At Merton Highway, below Messrs. Shears' mill, there is a drain pipe 6 inches in diameter, into the river. A drain also comes down from Wimbledon, by the copper works, flowing freely. Below Merton Bridge, a small spring flows from a well in a garden, and passes by an iron pipe under Messrs. Child's mill road, into the river; the bore hole is said to be carried down 340 feet into the chalk. The next mill head is a considerable body of water above Messrs. Child's flour mills, where there are two wheels equal to 40 H.P.; the mill head is 27 feet 8 inches above T.H.W.M. An overfall on the eastern side, conveys the waste water into the River Graveney. A small overfall on the western side runs to waste, till it joins the Wandle below Mr. Payton's leather works, at Messrs. Child's mill tail.

Immediately below the mill, the River Graveney enters the Wandle, the level being 22 feet 10½ inches above T.H.W.M. This is a considerable tributary, with a dirty appearance, when the Wandle itself is comparatively clear. The water was so high, that the top of the arch could not be seen, nor could its dimensions be ascertained; but from an observation made at Tooting, it was fully 6 feet in the clear under the turnpike road to Mitcham.

The following gaugings per day, have been taken at this point:

	No. 13. Mill Stream. Gallons.	No. 14. River Graveney. Gallons.
No. 1 . . .	..	3,780,000
„ 2 . . .	..	6,291,000
„ 3 . . .	33,261,210	2,196,000
„ 4 . . .	..	1,458,000

To the above quantities must be added the waste water, which was not determined.

On the west bank of the river are Mr. Parson's leather japanning works, which are supplied with water from an Artesian fountain, rising about 8 feet above the surface. A portion of the water is contaminated, and enters the river.

In the neighbourhood of Tooting and Summers Town, there are several Artesian bore pipes visible, which rise above the level of the ground. The soil about this part, is well charged with water, which flows readily. About half way between Messrs. Child's mill and Summers Town, there was a good flow of water down a brook on the west side, proceeding from the uplands towards Wimbledon.

At the copper mills of Messrs. Pontifex, which employ three wheels equal to 50 H.P., there is an overfall on the east side of the mill head, which joins the eastern mill tail. The mill head is 22 feet ½ inch above T.H.W.M. There are two sluices, east and west of the mill head, besides a third in the mill; and a small drain from the field empties itself into the tail of the western sluice. Lower down are Mr. Heath's print works. A small cut on the eastern side of the river supplies water, for rinsing and washing the goods. The machines are fixed in the stream, and deep colouring matter is mingled with the water of the river. On the east bank, are two drains from the house at the print works. There was a small drain from the west side to a brick pug mill, not in use. At the north end of the print works, a small drain enters the river, on the west side. The river now divides itself round Mr. Lee's grounds, and supplies two considerable reservoirs on the eastern bank, uniting in one stream at Mr. Garrett's oil mills, the head being 16 feet 2½ inches above T.H.W.M. At the mill head of Mr. Garrett's oil mills is a large waste sluice, leading the water under the railway, where it rejoins the main stream. The gaugings taken here per day are:—

No. 15. Mr. Garrett's Oil Mills.

	Gallons.			
No. 1 . . .	83,469,060	or	9,274	cubic feet per minute.
„ 2 . . .	76,316,950	„	8,479	„ „
„ 3 . . .	62,343,000	„	6,927	„ „

Against the mills on the east side is an overfall, and also another sluice. These mills employ two wheels equal to 45 H.P., and a steam engine equal to 20 H.P. At this point also, the open drain from Tooting and the County Lunatic Asylum discharges its water into the Wandle, the level being 11 feet 1 inch above T.H.W.M. The arches of the culverts under the roads from this drain, are 3 feet in diameter. At a short distance north of the railway, a brook from Wimbledon Park flows into the Wandle, on the west side, as well as two, or three land drains. About a quarter of a mile lower down, the river divides, the principal stream setting eastward, while the other branch is nearly filled with mud, and very little water flows through it. This receives the last land drainage along the western side. At the shawl printing works of Messrs. Bender and Thompson, the water was observed to be tainted with dye; and the parchment and colour works occupied by Mr. Townsend, used about 2,000 gallons of water daily, which was also contaminated. The river again forms one stream opposite Mr. Wallis's, the horse slaughterer's. An open drain from this yard passes along a meadow, and thence by a pipe under the Wandle, into an open drain on the west side, running northwards, until it meets the waste of Mr. Easton's mill. The Wandle being now embanked for the remainder of its course, is free from side drainage. At the mill head of Mr. Easton's paper mills, is a waste sluice and waterfall, the head water being 10 feet 6 inches above T.H.W.M. The wheel power is equal to 16 H.P. These works use a considerable quantity of water for bleaching and washing the rags, with the addition of a strong solution of alkali, amounting to not less than 200,000 gallons daily, which is returned into the river. Alongside the tail of this mill, is an overfall on the west side, over which the waste water flows into an open ditch through flat meadows, finally emptying itself, added to other sewage, a little above Wandsworth Bridge, into the River Wandle.

On arriving at Messrs. Watney's upper mill on the west side, there is a reservoir supplied from the mill head, though intercepted by the works; the head water is 7 feet 7 inches above T.H.W.M. At the mill head is a sluice and two small overfalls; when the level of the overfalls was taken, it was 6 inches below the head. The two wheels are equal to 47 H.P., and there is a steam engine of 20 H.P.

At Wandsworth Bridge, which is about 7 chains below the upper mill, is an overflow weir on the west side, the level being 2 feet ¾ inch above T.H.W.M. This weir receives part of the surplus water of the river, in a sewer 3 feet in diameter, which passes down the High Street, and thence, turning by the Church northward, discharges itself into a creek of the Thames, at Mr. Downer's wharf, 2 feet 8½ inches above T.H.W.M.

The level of the highest flood known in the Wandle, is shown on the plinth of the wall, east of Wandsworth Bridge, and is 5 feet 9 inches above T.H.W.M. Below Wandsworth Bridge on the east side, a culvert 2 feet in diameter, empties itself into the river, draining all the streets for a long distance eastward.

On the east side of the river, there is a sewer down Garrett's Lane, 1 foot 6 inches in diameter, which crosses the High Street, passes by the brewery, and taking various streets in its course, finally passes under the railway basin, and empties itself into the creek, a little below the tail of the lower, or tidal mill, 11 feet 11½ inches above T.H.W.M.

The next mill, resuming the course of the river, is Messrs. Watney's middle mill for grinding corn, which employs two wheels equal to 34 H.P., at the head of which is a sluice and tumbling bay. The head water was 1 foot 6½ inches above T.H.W.M., and the tumbling bay, 1 inch below the then existing head. On the east side of the mill tail, are large sluices for the purpose of letting off the waste water, from the adjoining railway basin. They also serve to supply the basin from the Wandle, at neap tides, when it will require a depth of water of about 1 foot 6 inches, to keep up the proper level. At the end of the creek, on the west side of the river, are two large sluices for draining off the water of the Wandle. The last mill on the Wandle, known by the name of the lower, or tidal mill, also belonging to Messrs. Watney, is prevented, by the flow of the tide, from working during six to eight, out of twenty-four hours. The power is derived from three wheels, collectively equal to 45 H.P. and a steam engine equal to 18 H.P.; the head water is 1 foot 8 inches above T.H.W.M. At the mill head, there are two overfalls, over which the tide frequently flows from the River Thames, and even, occasionally, so much as to reach the middle-mill head.

The watershed of the River Wandle comprises 16,875 acres, of which 3,940 acres are unavailable; and that of the Collier Brook is 4,670 acres; making a total of 17,605 acres.

	M.	F.	Yds.
The distance from Croydon to Wallington is	2	4	42
,, ,, Wallington to Merton	3	1	79
,, ,, Merton Abbey to Wandsworth	3	5	12
Total	9	2	133

The number of mills, of which a list is given in the Appendix, (page 208,) is thirty-eight, with an aggregate water power equal to 781 H.P.

Observations on the Gaugings.—According to the gaugings of the River Wandle, the total flow varied at Mr. Garrett's oil mills, from 83,469,060 gallons to 62,343,000 gallons daily, and that of the River Graveney, during the same time, from 6,291,000 gallons to 1,458,000 gallons daily. These quantities refer to a period when the river, its bed, and the adjacent soil, had been saturated with heavy rains; they, consequently, afford no criteria of the quantities during dry seasons, when the gravelly district not only refuses to part with its water, but even robs the river itself of water, which flows down from a district less influenced by evaporation. It may be concluded, that in a season of drought, the true source of supply to the Wandle is to be found at Waddon and Carshalton only, for the Bourne becomes dry and the Croydon springs are polluted. At present, (1853,) the supply from Waddon and Carshalton is found to amount to 32,941,800 gallons daily, but when the land springs and other drainage waters are exhausted, there are only 18,367,920 gallons daily, available for water supply, supposing the flow from the chalk to continue uniform. But when this water reaches Wandsworth, much has been evaporated and filtered into the gravelly soil, and much has been polluted and carried away as sewage, or consumed in the works, so that about 10,000,000 gallons is, probably, the only quantity which could be relied upon, and this, as before mentioned, is unavoidably polluted.

In the Appendix, (page 208,) is given a summary Table of rainfall, illustrative of the quantity which, during floods, may be expected on the tract of country through which the River Wandle flows. Part of it is absorbed into the land to form the various springs of the district, another part is evaporated from the surface, and the remainder drains into the river along its banks, or its main tributaries. This Table especially applies to that portion of the district, where the nature of the soil is non-absorbent; viz. the tract of land drained by the River Graveney and Collier Brook, embracing part of Streatham, Norwood, and Croydon, as also Tooting and Mitcham; the water flowing over a clayey soil, and bringing with it the sewage of many houses, into the Wandle. The area of this tract is estimated at 4,900 acres, and the drainage is finally discharged, as before mentioned, through culverts, the total area for flood waters, being only about 50 square feet.

APPENDIX.

SUMMARY OF THE GAUGINGS OF COLLIER BROOK, OR RIVER GRAVENEY.

—	Rainfall, in Inches.	Imperial Gallons, per Month.	Imperial Gallons, per Day.
1852. September	3·48	385,758,000	12,858,600
October	4·00	442,960,000	14,755,333
November	6·14	680,821,000	22,964,938
December	1·92	212,830,000	7,094,937
1853. February	—	—	6,291,000

According to observations made from time to time, during the month of February, 1853, on the flow of flood water through the present culvert, which presents an area of 50 superficial feet, it was found, that it took seven days to discharge the flood and restore the Collier Brook, or River Graveney, to its usual level.

LIST OF THE MILLS ON THE WANDLE.

Owners.	Description.	Above T.H.W.M.		Estimated H. Power.
		Ft.	In.	
Sawyer	Flour	104	9	7
Charrington	Ditto	107	4¾	24
Muggeridge	Paper	104	9	15
Hedgecock	Snuff	99	9	9
Ansell	Ditto	83	1½	16
Ashby	Flour	”	”	16
Chasemore	Ditto	116	9½	25
Lambert	Snuff	105	7	25
Holloway	Flour	82	2½	12
Mears	Oil and Felt	75	1¾	32
Darling	Flour	67	2	20
Bourne	Ditto	64	2	14
Atkins	Dye	”	”	12
McCrae	Leather	”	”	16
Sprule	Dye	58	0	30
Searle	Flour	”	”	28
Arney	Gelatine	56	2½	6
Jones	Felt	53	2	23
Glover	Flour	”	”	24
Ashby	Ditto	”	”	20
Dempsey and Hind	Print	46	7	8
Rutter	Snuff	47	0	21
Hatfield	Ditto	41	7	20
Welch and Margetson	Print	36	9¾	8
Littler	Ditto	34	10	15
Welch	Ditto	32	4½	8
Shears and Sons	Copper	33	1½	50
Child	Flour	27	8	40
Pontifex	Copper	22	0½	50
Garrett	Oil	16	2½	45
Easton	Paper	10	6	16
Watney	1. Flour	7	7	47
Ditto	2. Ditto			
Ditto	3. Ditto	1	6½	34
Ditto	4. Ditto			
Ditto	5. Ditto	1	8	45
Ditto	6. Ditto			
Ditto	7. Ditto			
				781

N.B. Many of the mills have additional steam power.

[Mr. BIDDER,

Mr. BIDDER,—President,—observed, that although the Paper treated of an unimportant river in the neighbourhood of London, it opened out questions of great social and scientific interest; the water supply, water rights, the pollution of rivers, and the remedies that ought to be applied, consistently with the improvements now taking place in social science, and with the drainage of the towns and the villages in the vicinity. He resided near the Wandle, and was the owner of the mill, on that portion of the stream, which passed through his land. There were circumstances connected with that river, interesting and important to the residents and owners of property in its vicinity. The town of Croydon was under the operation of the Health of Towns Act, and under the provisions of that Act, a well had been sunk, and water had been pumped from the Wandle for the consumption of the inhabitants, and also for the purposes of sewage. That proceeding had been contested at law; but it was finally decided by an appeal to the House of Lords, who held, that the possessor of the soil might sink a well, and pump from it to any extent, however much it might affect his neighbours. Now although that judgment seemed, at first sight, to be dictated by common sense, yet on reflection, it was doubtful whether it could be approved, especially when the owner of the well applied the water to other than his own wants. But the Croydon Board of Health were now extending the judgment in that sense, by intercepting the mouth of the Bourne, by a sewer which was carried at a lower level, to the vicinity of Croydon, upon the pretext of rendering the foundations of the lower part of Croydon, drier than heretofore. There was also the question of pollution, for the whole drainage of the town of Croydon was carried into the Wandle. After much contention on this subject, the authorities constructed a drain, partly open and partly covered, in the direction and close to the parish of Mitcham. Having found the fish in his own portion of the river, rapidly diminishing from this cause, he had taken legal proceedings, the result of which was, that the authorities undertook to remove any nuisances they might have created. There were various other pollutions from minor causes, of scarcely less importance; but they were only particularly obnoxious, at certain seasons of the year.

The flow of water in the Wandle was subject to peculiar vicissitudes, not alluded to in the Paper. During the greater part of the year 1858, the quantity of water flowing down that river, was not one-fourth of the present quantity, and in consequence, the mills were stopped, for not less than eight, out of every twelve hours. In addition, the Wandle had been, of late, over-run with a weed, possessing little buoyancy, and which collected great quantities of mud. It was supposed to have come, originally, from America, and it had fructified in this country to an extraordinary extent, and interfered, in some measure, with the sanitary condition of the fish.

He hoped, that this discussion, although raised upon the condition of the Wandle, would take a wider range, as the questions which it involved, had an important bearing upon the past, the present, and, most certainly, the future of almost every river in England; and unless precautionary measures were taken, the condition of many rivers which, heretofore, had been ornaments to the estates, and sources of comfort to the residents in their vicinity, and who were the owners of the fish of those streams, would become deteriorated, and would occasion serious detriment to the surrounding property.

WATER SUPPLY AND LAND DRAINAGE.[1]

Mr. FREDERICK BRAITHWAITE said, he had been induced to prepare this Paper, embodying the results of a careful study and survey of the Wandle, in consequence of the recommendation of the President, in his Inaugural Address,[2] to investigate the condition of the rivers of England. The supply of water for the rivers had become an important question; for instead of that supply being inexhaustible, as had been sometimes asserted, there was an actual deficiency. The last year was an exception to the rule, for from September, 1859, to September, 1860, the rainfall exceeded by 11 inches, the average of the ten, or twelve previous years. In 1858, the excessive heat and the deficiency of water occasioned, in many rivers, the destruction of great quantities of fish, and at one period, the water ceased to flow. It was to be regretted, that the Wandle, which might, at little expense, be made a useful and powerful auxiliary to the water supply of London, should be allowed to remain in its present condition.

Mr. Braithwate, after alluding to Tables of the average monthly rainfall for the last twenty years, and of the daily rainfall for 1856, said, that the state of Mr. Dickinson's rain gauge, distinctly proved, that during the hotter months in the dry seasons, little water penetrated the ground, even to the depth of 3 feet, the depth of the rain gauge; it must be evident, therefore, that to calculate the supply of water to rivers, by averages, was a very unscientific mode of calculation. The actual amount could not be properly estimated, without taking into account the state of the weather, and not merely the quantity of rain, but also the time in which it fell. The available supply greatly depended, however, upon the absorbent powers of the soil. He had found, that a piece of chalk which, when dry, weighed 2 oz. 7 dwts. 7 grs., increased 13 grs. in weight, when saturated with water; at which rate, a cubic foot of chalk of the same density, would absorb nearly 4¼ inches of rainfall. Evaporation and absorption must also be carefully considered, in estimating the quantity of water supplied to rivers.

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[1] The remarks made during this discussion, have been arranged under the following heads: 1st, Water Supply and Land Drainage; 2nd, Pollution of Rivers, Town Drainage, and Sewage; 3rd, Water Rights.

[2] *Vide* Minutes of Proceedings Inst. C.E., vol. xix. page 221.

With regard to agricultural drainage, he thought that, generally speaking, sub-drainage was wanted, only where the excess of surface water was due to other causes than the rainfall, and in his opinion, the system was often carried out to too great an extent.

Mr. Simpson, (Past-President,) observed, that beyond Croydon, the geological character of the district traversed by the Wandle, was peculiar, and there were some remarkable circumstances connected with the watershed. He had been conversant, since the year 1815, with the flow of the Bourne. The gaugings had, evidently, been taken by a careful observer of the phenomena of that stream, and they were a record of its periodical variations, the cause of which had been correctly stated in the Paper. The flow was never exactly at the same period: when heavy rain had fallen at the latter part of one year, the Bourne might break out in the following January, or February. The President had remarked, that the Wandle was not an important river, but within a recent period, there was scarcely a stream of the same length, which presented a greater amount of manufacturing industry; there were thirty-five mills within a distance of nine miles, all fully employed. Circumstances had, of late years, altered the industrial character of the river; manufacturing trades in the vicinity of London had declined, and in many instances, steam engines, at present, performed the work in London and in some of the provincial towns, which was formerly effected by the water wheels. Still the Wandle was an important stream, for at certain seasons, it had a continuous large supply of water from the chalk. The Author's gaugings accorded closely with his own, although not taken at the points mentioned in the Paper, because his own attention had been confined to ascertaining the flow of the river. In 1858, at Garrett Mill, the total volume of the stream, for many months, did not exceed 11,200,000 gallons per day; and on several days he had no doubt the amount was less. The Author had recorded 83,469,060 gallons as the largest flow; yet at the same place, but at another time, 92,000,000 gallons per day, had been measured. Such an extraordinary fluctuation was not usually met with, in a stream issuing from the chalk. The Bourne never flowed for many months at a time, but a large quantity of water which produced fluctuation in the Wandle, came from the area feeding the lower part of the stream below Croydon, a large portion of which was clay land. The effect of this was, however, equalised to some extent, by a number of large ponds, including the lake called Collyer's Water, in connection with the river.

From personal observation, without reference to gauging, it had appeared to him, that of late years, the lower parts of the stream had been subject to great fluctuations, and he attributed it, in some measure, to the extension of land drainage. In the Wandle valley, as well as in many other parts of the country, it was found, that the water from the rainfall ran quickly off the land through the drain tiles, into the brooks, and percolation was thus, to a great extent, prevented.

Sir JOHN RENNIE, (Past-President,) said, that the arterial drainage of large towns, and the extensive under-drainage of land, induced by the progress of civilisation, had materially affected the condition of the rivers throughout the country. The greater part of the rainfall was now discharged, almost as soon as it reached the ground, into the rivers and streams; floods, consequently, were more rapidly carried off, and in dry seasons there was great scarcity of water. Fifteen years ago, when he had the honour of occupying the Chair of the Institution, he pointed out the necessity of economising water during the winter, and the proper means of utilising it during the summer.[1] In rivers near the sea, unless means were provided for back discharge and for first carrying away the alluvial matter brought in with the tide, so as to preserve the equilibrium between the tidal and the fresh water, the former possessing a superior influence, would, eventually, deposit it in the bed of the stream. Many important questions had been raised by this Paper, and he hoped the attention of the Members would be directed towards the extensive field of inquiry it had initiated.

Mr. GIBBS said, that the Wandle, though a short river, presented many interesting features, mechanically and geologically. Mechanically, because some of the best mills in England were built upon it; there was one by Smeaton, and another by Rennie, which were models to be followed, even at the present day, being constructed upon true principles. It was interesting, geologically, because of the large volume of water drawn from the chalk hills, in so short a distance. This was owing to the upheaval of the chalk, and, consequently, of the London clay, between the Rivers Wandle and Cray, so that it was impossible for any great amount of water to escape from the chalk between Croydon and Carshalton. The Ravensbourne was a stream issuing from the chalk, in a large valley, with a very small quantity of spring water. The disturbance he had mentioned, accounted for the gradual depression of the springs, from Croydon towards the River Mole, which although it ran through the chalk, did not proceed from it. From London to Rochester and Chatham, no springs came out of the chalk, in sufficient copiousness to form a river; the chalk was intercepted by the Wealden clay, and the water passed through and between the chalk downs. Along this line of country, as there was no disturbing cause, the water issued from the chalk, in almost imperceptible streams; but between Croydon and the River Cray, there were disturbing causes, and the Wandle, in consequence, became a comparatively large stream. There was an impression, that what was called the Bourne, above Croydon, was a periodical river, which broke out about once in seven years, but it was, in reality, nothing more than the superfluous rainfall, when the rain had been very copious and long continued, which could not be absorbed by the gathering ground, and was, consequently, raised to a higher level. But when the power of absorption became superior to the amount of rainfall, the Bourne ceased to flow. Similar instances were not unfrequent; a stream occasionally broke out at West Wickham, between Croydon and the River Cray, when the chalk became incapable of absorbing the whole of the rainfall, and of transferring it to the springs.

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[1] *Vide* "An Account of the Drainage of the Level of Ancholme, Lincolnshire;" Minutes of Proceedings Inst. C.E., vol. iv., p. 186.

Allusion had been made to the great absorbing powers of the chalk, but absorption by immersion, should not be confounded with absorption by capillary attraction; in the latter process, a less proportion of water was taken up by the chalk. The objection to averages of rainfall, in calculating the available quantity of water from drainage grounds, did not affect the question, for it was the minimum that was, generally, relied on. But with regard to the rainfall, it was important to bear in mind, that the quantity of water which might be expected, was much influenced by the state of the atmosphere before the rain fell; because, if the ground was exceedingly dry, and the sun was powerful, the rain would be nearly all evaporated, leaving scarcely any available. There had often been an erroneous impression, as to the proportion of the rainfall upon chalk, which was really available, and too much was generally calculated upon. The real quantity penetrating the chalk by gravity, after the water had sunk beyond the influence of the atmospheric temperature, had not been, in some cases, more than 5 inches, or 6 inches in the year, out of an amount of rainfall of 28 inches.

Mr. Hawksley said, that the Paper had introduced so large a number of topics, that it was difficult to select those which were more immediately important, and bore most directly upon the particular conditions and circumstances of the River Wandle. The area of drainage of a river could, as a general rule, be approximately determined; but the case of the Wandle was exceptional. Its actual drainage consisted only of a few thousand acres; but beyond that obviously visible and measurable area, there was a large tract of chalk country, which discharged its waters, not by streams, but chiefly by springs, flowing at a considerable distance from the point of rainfall, and under very unusual circumstances. Some of the springs were intermittent, not showing themselves more than once in five, or seven years, and then, perhaps, discharging as much as 20,000,000 gallons per day. The principal one was the River Bourne, which thus became the occasional head of the River Wandle; that river was now flowing at the rate of about 20,000,000 gallons per day. In considering, therefore, the conditions under which the Wandle was produced, it was necessary to take into account the rainfall, which was subject to great variations. In the neighbourhood of London, and in that particular district, it descended, in some years, as low as 16 inches, and in others, it rose to 33 inches, the average being about 23 inches.

The question had been raised both by the Paper and in the discussion, as to the amount of water which usually flowed off the ground and became contributory to rivers. It had frequently been asserted, that the rainfall might be divided into three equal portions, one of which was disposed of by evaporation, another by absorption, and the third by superficial flow. That statement was erroneous, for the amount of evaporation was very nearly a constant quantity. In the neighbourhood of London, it varied from about 15 inches, in some years, (14 inches was the minimum, and it was rarely lower than 15 inches,) to 18 inches, and as much as 19 inches; but the average evaporation in that and similar districts, might be taken at about 16 inches, or 17 inches. As the average fall of rain was about 23 inches, there would only be a residue of about 6 inches, or 7 inches, and it appeared, from the best information respecting the discharge of the Thames, a river produced from the drainage area of about 6,000 square miles, that such was the amount of discharge from the chalk area. At a period of maximum drought, as in 1850, when all the water which descended the river, proceeded from springs, the discharge was at the rate of about 2 inches per annum, during two, or three months. Under these circumstances, it was easy to account for the extraordinary changes that occurred in the volume of the River Wandle. That river, although deriving its chief supply from a chalky district, had fluctuated, by actual measurement, from a minimum of about 10,000,000 gallons, to a maximum of about 90,000,000 gallons: at periods of great rain, it must, of course, exceed that quantity. In mountainous districts, and near the heads of the streams, where he had been able to make observations over long periods, he found the minimum to be about one-sixteenth of the average flow, and the height of floods to be more than sixteen times greater than the average flow, the ratio between the minimum and maximum quantities being about 1 to 300. In the Liverpool watershed, where the rainfall was chiefly upon rocky ground covered with clay, after elaborate gaugings during several years, the evaporation was found to vary from 10 inches to 14 inches per annum. The great bulk of the water was produced by the floods, and in the summer months, the yield from the springs was so small as, practically, to be of no value. A distinction should, therefore, be made, between a rocky precipitous district, and a chalk formation consisting mainly of flat table land; and in a pecuniary point of view, the difference was highly important. In the Wandle, the extremes were incomparably less than in the cases alluded to; in that district, the water was, therefore, proportionately more useful; the flow being more regular, it was more beneficial to the mill property, and more valuable for ornamental purposes.

In the Wandle district, an operation was now being carried on which had been found, in many parts of the kingdom, to be almost destructive of the value of water power. It was absolutely certain, that the effect of under-draining had been, in many cases, to diminish the flow of the rivers in dry weather, and to augment it in wet weather; thus increasing both the droughts and the floods. Valuable as was this system in many points of view, it was frequently carried to such an extent, that it had the effect of desiccating the soil, and even rendering it sterile. It was just as possible to carry off too much, as too little of the under-water; and it was well known amongst the agriculturists of the fen districts, whom he believed to be the best in the kingdom, that if water was drained below 30 inches, or 3 feet, the crops materially diminished in weight. The greatest possible differences of opinion, however, existed, as to the depth of drainage and the systems employed. Some professors always adopted the 4-feet system; others, the 6-feet system. Some always employed pipes of 1 inch, or 2 inches; others, drain tiles; and others, again, large stones. The necessary effect of any fixed system was, sometimes, to deteriorate much of the land, by removing from it water which was required for the growth of the crops, and at other times, to leave water which was redundant. In certain soils of Worcestershire and other counties, where there was a 'pan' of gravel underlying the productive soil, that 'pan' had been frequently tapped to such a depth, that the water was drawn through the land as through a sieve, and the soil became dry even a few days after rain; in seasons, therefore, of even moderate drought, the crops were scarcely able to grow.

Mr. Hawkshaw, V.P., wished to point out the danger of too much generalisation on engineering subjects. It might happen, under certain conditions and in certain localities, that the rainfall could be divided into three equal parts, of which one-third was evaporated, one-third was absorbed by vegetation, and one-third ran off the soil; but this division should not be established as a general rule. It had also been stated, that the drainage of the land necessarily increased the floods. It was obvious, that the effect of draining certain soils might be, to give them such a texture as would cause the rainfall to be first absorbed, and afterwards evaporated; so far, therefore, from causing floods, it would, in these cases, have the effect of preventing them.

Mr. HOMERSHAM remarked, that it had been dogmatically laid down, that in a dry year, only 6 inches, or less than one-third, or one-fourth of the total rainfall, sank into the drainage grounds of the Wandle and the Thames. The proportion would, however, depend, in a great measure, upon the quality of the ground. Thus a rainfall of 1 inch, in ten, or twelve hours, would nearly all run off a hill of clay, or primitive rock, almost as soon as it fell; this he had ascertained, both from experiments and from personal investigation. But on the steep chalk hills round London, some of which were at an elevation of 800 feet, or 900 feet above the level of the sea, although there might be a rainfall of 2 inches in an hour, as sometimes happened, the whole of it would sink into the ground. So also with the red sandstone formation, the water was absorbed almost as fast as it reached the earth. He had sunk into the gravel, or Woolwich pebble-bed, overlying the chalk, a well, 5 feet in diameter and 37 feet deep, and he had poured into it for many hours together, as much as 2,000 gallons of water per minute, yet he had never been able to cover the bottom of the well to the height of 1 inch, the water being absorbed at once. There were large districts of a similar absorbent character round London and elsewhere, and on such drainage areas, the whole of the water entered the ground immediately, especially during heavy rains; very little of this water was lost by evaporation, or was taken up by vegetation, which, in such situations, was, generally, of the most scanty description. On clay lands, especially when flat, a larger quantity of rain was taken up by vegetation and given off by evaporation, than on chalk hills.

It was stated in the Paper, that the quantity of water immediately below Waddon Mill, was 19,000,000 gallons per day; but Mr. Telford, who gauged the river, in 1833, at the same place, reported it to yield, in dry seasons, only 9,000,000 gallons per day. It was true, that in a wet year, the quantity would be increased, but Mr. Homersham did not consider 1853 to come under that category, and he thought, that the former quantity was largely in excess, when taken as a minimum. At, or near Hack Bridge, the Author had reported the gaugings at about 63,000,000 gallons per day. Now Mr. Homersham had found, by actual measurement, that the drainage ground of that point was about 55¾ square miles, and to produce that quantity of water, a depth equal to 29 inches of rainfall per annum, must flow off the ground. In the course of the discussion, it had been said, that it was scarcely possible to define the drainage ground of the Wandle; from this he dissented, as in 1855, he had ascertained it to be, at the point before mentioned, about 56 square miles.

Mr. Fenton said, the Paper purported to contain a description of the Bourne, which accorded with the popular ideas upon the subject, but after a careful investigation, he was convinced those ideas were incorrect. The Bourne was not an intermittent spring, but it was constantly flowing underground, between the Godstone quarries and the Bourne culvert at Croydon. The original springs rose at the lower end of the three tramways which passed down the quarries, at about two miles from the Caterham Station. Even in 1858, an unusually dry season, the quantity of water at that point, was about 200 gallons per minute. The flow above ground varied with the rainfall; but the flow underground from the quarries and from other sources into the culvert, was 500 gallons per minute. The general idea was, that the Bourne originated in Marden Park; but the spring did not rise there, until the quarries were two-thirds full, containing nearly 15,000,000 gallons of water, when the other outlets being insufficient for the discharge, it burst out in the park. The Bourne had three channels, of which the first was underground from the quarries to Croydon. The second was the channel originating in the neighbourhood of the quarries, but only appearing above ground, four miles below them, at the fifteenth milestone from Cornhill, to the north of the Warlingham Station, on the Caterham Railway. It began to flow out at this point, in November last; it was then a small stream, passing in an open channel for three-quarters of a mile, and it then disappeared below Roke's Farm, near the fourteenth milestone. That stream was now flowing at the rate of 1,400 gallons per minute; and the quarries were now two-thirds full. The third stream commenced near Marden Park, about half a mile beyond the Warlingham Station, on the road to Birch Wood, and was now discharging 300 gallons per minute. That stream only commenced running, in the beginning of the present month of February; so far, therefore, from the Bourne springing up in Marden Park, it was only when the first and second channels were overcharged, that it burst out there. The combined waters from Marden Park and from the second channel, were now running below Riddlesdown, at the rate of 1,500 gallons per minute; but the flow from the mouth of the Bourne culvert, which also received the water from the vicinity of Mersham, was 3,500 gallons per minute. The underground channels would thus appear to be discharging 2,000 gallons per minute. The under-stratum of gravel and chalk was so porous, that notwithstanding the discharge of 1,400 gallons per minute, at Roke's Farm, the water ran above ground at the present moment, to within a short distance of the Caterham Junction, where it entirely disappeared.

Mr. HAWKSLEY, in answer to a question from Mr. Rawlinson, said, his observations upon evaporation were not meant to apply, either to the surface area of the whole of England, or to that of a large lake. He had argued, that from a surface of rock, the rain was rapidly shot off, in the same way as from the roof of a house, and there was, comparatively, little evaporation ; but that in chalk, sandstone, and free soil districts, a large quantity of water was first absorbed into the ground, and afterwards evaporated, exactly as it would be from sugar. In the northern parts of England, and in Scotland, the evaporation was less than in the south. In some parts of the north, the evaporation descended to 12 inches, or 13 inches, even upon soils of that description, whilst in exceptional parts of the kingdom, it ascended to 18 inches, or 20 inches. In the neighbourhood of London, the mean evaporation from the surface of the chalk was, on the average, about 16 inches, or 17 inches per annum, and from the surface of water, nearly 36 inches. In an exceptionally wet year, like 1860, more water descended into the earth than in a dry year, like 1859, and there was also less evaporation. In a dry summer there was, of course, very little water to be evaporated ; but in medium years, with a great amount of rain falling lightly, and plenty of sunshine, there was a great amount of evaporation.

Mr. RAWLINSON had asked the question, because the amount of evaporation recorded by meteorologists, was from the surface of water, continuously and freely exposed, over which the power of the atmosphere was, necessarily, greater than over the drainage ground of the River Wandle. The amount of rainfall in the neighbourhood of London, varied, he believed, from a minimum of 16 inches in a dry year, to a maximum of 32 inches in a wet year, or as 1 to 2 ; and from all the information he had been able to collect, it appeared, that within a range of thirty, or forty years, a similar variation extended not only over this district, but over the greater part of the globe, in all countries, and in all climates. It was highly probable, that there was the same annual amount of sunshine, of heat and cold, and of evaporation and rainfall, over the whole surface of the globe, but it was unequally distributed. In tropical countries, the quantity of rain was considerably greater than in colder latitudes, and this was an important fact for the consideration of Engineers, in the construction of bridges, culverts, or waterworks. It had been stated, that the volume of water in some of the streams and rivers of this country, had been found to vary in the proportion of 1 to 300: he had known instances, however, where the variation was as great as 1 to 500. But in tropical and semi-tropical countries, there was a much wider margin, as a dry ravine might become a destructive torrent, during thunder-storms and heavy rains; many inches of rain falling within a few hours.

He thought the question of land drainage might safely be left to the agriculturists, who would not be likely to expend large sums of money upon deep drainage, in order to injure the soil and render it unfit for profitable vegetation. The Duke of Northumberland had drained land to a considerable extent, upwards of 20,000 acres, and always at a depth of from 4 feet to 6 feet; and he said, "he thought he might live to be considered a shallow drainer." The experience of Mr. Rawlinson was in favour of deep drainage, and he thought, that so far from drains acting as so many culverts to carry off all the water from the land, they seemed to economise it.

Mr. JOHN EVANS said, that living in a chalk district of Hertfordshire, and being dependent upon chalk streams for the supply of motive power to numerous mills employed in the manufacture of paper, the firm with which he was connected, had endeavoured to ascertain the amount of rainfall and of percolation, through the soil of that district. In 1843, and again in 1850,[1] his late partner, Mr. Dickinson, had communicated to the Institution, the results of those experiments, and Mr. Evans thought it desirable to place the Institution in possession of a continuation of Mr. Dickinson's register of rainfall and percolation, up to the present time. In these Tables, (pp. 220-224,) the year was made to commence on the 1st of October and to terminate on the 30th of September, the first six months being taken as the winter half of the year, and the last six months as the summer half. It would be observed, that by far the greater amount of percolation, took place during the winter months, there being frequently none whatever during the summer, and the average summer percolation through the soil, during twenty-five years, being less than three-quarters of an inch. The maximum winter rainfall, = 20·27 inches, was in 1852-3; and the maximum percolation, = 17·98 inches, was in 1841-2. The minimum winter rainfall, = 8·58 inches, was in 1849-50; and the minimum percolation, = 0·9 inch, was in 1858-9. The maximum summer rainfall, 20·40 inches, was in 1860; and the minimum, 8·07 inches, in 1843. Though the annual average of rainfall of the last seven years and of the previous eighteen years was nearly the same, yet the proportions of the winter and summer rainfalls, were 13·86 to 12·79, in one of these periods, and 11·91 to 14·58, in the other; and the average winter percolation was reduced from 8·635 to 4·601.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. ii., 1843, p. 160, and vol. ix., p. 158.

TABLES of RAINFALL and PERCOLATION through DALTON'S GAUGES, filled with Surface Soil and Chalk, at Nash Mills, Hertfordshire.

	1833-4		1834-5		1835-6		1836-7		1837-8		1838-9		1839-40		1840-1	
	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.
October .	2·55	..	·81	..	5·96	4·75	4·55	3·82	1·55	·02	2·68	·07	1·68	·09	1·50	..
November.	2·22	..	1·96	..	2·10	2·17	3·95	3·14	2·05	·18	3·55	2·91	4·40	4·70	4·25	2·57
December.	4·03	..	·84	..	·24	·48	2·21	1·82	1·70	1·62	1·58	1·84	3·02	3·75	·40	..
January .	3·32	..	1·20	..	2·40	2·32	2·40	2·10	·31	·04	1·40	1·04	3·95	3·05	1·50	..
February .	·75	..	2·62	..	2·04	2·04	2·85	2·92	2·65	·86	1·45	1·51	1·32	1·00	1·02	..
March . .	·75	..	3·48	..	3·65	2·51	·75	·01	1·55	2·73	1·92	1·22	·34	..	1·65	·53
	13·62	..	10·91	..	16·39	14·27	16·71	13·81	9·81	5·45	12·58	8·59	14·71	12·59	10·32	3·10
April . .	·60	..	1·67	..	2·57	1·74	1·32	..	1·35	..	1·65	·71	·34	..	1·85	..
May . .	1·50	..	2·05	..	·70	·03	·94	..	·84	..	1·22	·10	2·62	..	1·68	..
June . .	2·10	..	3·30	..	1·80	·01	1·86	..	2·85	..	3·31	·05	1·33	..	3·00	..
July . .	5·10	..	·80	..	2·29	·10	1·30	..	2·35	·09	4·36	·15	1·18	..	2·80	..
August .	2·47	..	·35	..	2·24	·15	3·00	·05	95	..	3·65	·09	1·90	..	3·62	..
September	1·50	..	3·82	..	2·60	·07	1·38	·05	2·47	·03	3·22	1·50	2·31	..	4·00	..
Summer .	13·27	..	11·99	..	12·20	2·10	9·80	·10	10·81	·12	17·41	2·60	9·68	..	16·95	..
Winter .	13·62	..	10·91	..	16·39	14·27	16·71	13·81	9·81	5·45	12·58	8·59	14·71	12·59	10·32	3·10
	26·89	..	22·90	..	28·59	16·37	26·51	13·91	20·62	5·57	29·99	11·19	24·39	12·59	27·27	3·10

Tables of Rainfall and Percolation through Dalton's Gauges—*continued.*

	1841-2		1842-3		1843-4		1844-5		1845-6		1846-7		1847-8		1848-9	
	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.
October .	4·40	5·99	1·41	·30	4·82	·91	4·38	1·13	1·65	..	6·36	3·98	2·59	..	4·50	2·58
November .	4·28	4·87	5·77	5·00	2·45	2·70	3·07	3·57	2·94	·30	1·47	·10	1·70	..	1·12	·47
December .	2·30	2·80	1·52	·84	·40	·30	·31	..	3·02	2·80	·90	..	3·49	2·38	2·92	2·68
January .	1·36	·60	1·46	1·25	1·90	·80	3·35	2·40	3·97	5·05	1·80	..	1·33	·81	1·80	..
February .	2·02	2·10	2·42	1·95	3·62	1·50	·70	..	1·28	·84	1·42	1·76	3·25	3·00	2·18	·40
March . .	2·20	1·62	·88	..	2·22	2·65	1·30	..	1·07	·02	·98	..	3·57	2·75	·97	·09
	16·56	17·98	13·46	9·34	15·41	8·86	13·11	7·10	13·93	9·01	12·93	5·84	15·84	8·94	13·49	6·22
April . .	·47	..	2·10	..	·33	..	1·45	..	2·52	·28	1·68	..	2·68	·70	2·00	..
May . .	1·85	..	5·00	·74	·47	..	2·25	..	1·59	..	2·15	..	·21	..	2·98	..
June . .	2·00	..	1·56	·25	1·18	..	1·60	..	·51	..	2·30	..	3·19	..	·46	..
July . .	1·93	..	2·09	..	1·95	..	2·30	..	1·90	..	1·91	..	2·42	..	2·79	..
August .	1·40	..	2·66	..	2·72	..	1·97	..	3·28	..	1·21	..	2·38	..	1·88	..
September	4·50	1·30	·63	..	1·42	..	2·00	..	1·70	..	2·06	..	2·12	..	3·80	..
Summer .	12·15	1·30	14·04	·99	8·07	..	11·57	..	11·50	·28	11·31	..	13·00	·70	13·91	..
Winter .	16·56	17·98	13·46	9·34	15·41	8·86	13·11	7·10	13·93	9·01	12·93	5·84	15·84	8·94	13·49	6·22
	28·71	19·28	27·50	10·33	23·48	8·86	24·68	7·10	25·43	9·29	24·24	5·84	28·84	9·64	27·40	6·22

Tables of Rainfall and Percolation through Dalton's Gauges—*continued.*

	1849-50		1850-1		1851-2		1852-3		1853-4			1854-5			1855-6		
	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Chalk.	Rain.	Soil.	Chalk.	Rain.	Soil.	Chalk.
October .	1·82	..	1·56	..	2·42	..	4·80	·80	3·60	1·65	1·82	2·23	..	..	5·47	..	3·00
November.	1·47	..	2·67	..	1·03	..	6·95	6·56	1·68	·57	·62	1·31	..	..	2·05	1·87	2·10
December.	2·50	1·03	1·66	1·39	·66	..	2·78	2·11	·65	·60	1·10	1·53	..	1·25	1·46	·92	1·12
January .	1·24	..	3·76	3·07	5·15	2·64	2·55	1·27	2·48	·95	·95	·79	..	..	2·97	2·28	2·40
February .	1·33	·41	·76	·85	1·15	1·02	1·44	..	·93	·45	·51	1·18	1·25	..	1·46	1·30	1·40
March . .	·22	..	4·30	3·18	·34	..	1·75	..	·32	..	..	2·28	1·20	2·20	1·07	·45	·45
	8·58	1·44	14·71	8·49	10·75	3·66	20·27	10·74	9·66	4·22	5·00	9·32	2·45	3·45	14·48	6·82	10·47
April . .	3·00	..	1·55	·04	1·13	..	2·60	..	·86	..	..	·40	·19	·22	3·10	·90	·90
May . .	1·67	..	·75	..	1·70	..	1·91	..	3·48	..	..	2·35	..	..	3·95	1·70	2·00
June . .	1·20	..	1·75	..	4·49	..	3·70	..	·97	..	..	1·76	..	·36	1·25	·19	·19
July . .	2·90	..	2·56	..	4·70	1·50	3·88	..	1·90	..	..	5·00	..	1·42	1·68	..	..
August .	1·14	..	2·00	..	4·08	..	3·00	..	1·75	..	..	1·43	..	·30	2·75	..	..
September	1·91	..	·64	..	3·87	..	1·70	·24	·51	..	..	1·72	..	..	2·13	..	..
Summer .	11·82	..	9·25	·04	19·97	1·50	16·79	·24	9·47	..	..	12·66	·19	2·30	14·86	2·79	3·09
Winter .	8·58	1·44	14·71	8·49	10·75	3·66	20·27	10·74	9·66	4·22	5·00	9·32	2·45	3·45	14·48	6·82	10·47
	20·40	1·44	23·96	8·53	30·72	5·16	37·06	10·98	19·13	4·22	5·00	21·98	2·64	5·75	29·34	9·61	13·56

Tables of Rainfall and Percolation through Dalton's Gauges—*continued.*

	1856-7			1857-8			1858-9			1859-60			1860		
	Rain.	Soil.	Chalk.	Rain.	Soil.	Chalk.	Rain.	Soil.	Chalk.	Rain.	Soil.	Chalk.	Rain.	Soil.	Chalk.
October .	2·92	..	1 45	5·80	1·70	3·40	1·94	..	..	3·03	..	1·90	1·65	·62	·75
November.	1·30	..	1·05	2·06	1·35	1·35	·78	..	..	3·09	1·70	2 20	2·70	2·30	2·30
December.	2·05	·60	1·65	·47	·18	·18	2·03	..	·30	3·30	2·80	2·90	2·40	1·26	1·12
January .	3·60	2·80	2·74	·70	..	..	1·21	..	1·02	3·53	2·95	3·08			
February .	·21	·32	·30	1·60	1·82	1·61	1·91	·09	1·37	1·22	·90	1·10			
March . .	1·88	..	..	1·18	·59	·62	1·77	..	..	2·32	·92	1·26			
	11·96	3·72	7·19	11·81	5·64	7·16	9·64	·09	2·69	16·49	9·27	12·44			
April . .	2·35	1·11	1·32	2·46	·80	·84	2·62	..	1·04	1·32	·35	·54			
May . .	·83	..	..	2·33	..	..	2·04	..	·06	3·67	·24	1·22			
June . .	2·20	..	..	·65	..	..	3·70	..	1·02	6·10	2·44	4·00			
July . .	1·70	..	..	2·63	..	..	3·80	..	1·20	2·22	..	..			
August .	3·38	..	..	2·40	..	..	2·40	..	·35	4·44	..	2·08			
September	3·65	..	..	1·80	..	..	3·75	..	·55	2·65	·13	1·10			
Summer .	14·11	1·11	1·32	12·27	·80	·84	18·31	..	4·22	20·40	3·16	8·94			
Winter .	11·96	3·72	7·19	11·81	5·64	7·16	9·64	·09	2·69	16·49	9·27	12·44			
	26·07	4·83	8·51	24·08	6·44	8·00	27·95	·09	6·91	36·89	12·43	21·38			

Tables of Rainfall and Percolation through Dalton's Gauges—*continued.*

	Winter.		Summer.	
	Rain.	Soil.	Rain.	Soil.
1835—6	16·39	14·27	12·20	2·10
1836—7	16·71	13·81	9·80	·10
1837—8	9·81	5·45	10·81	·12
1838—9	12·58	8·59	17·41	2·60
1839-40	14·71	12·59	9·68	..
1840—1	10·32	3·10	16·95	..
1841—2	16·56	17·98	12·15	1·30
1842—3	13·46	9·34	14·04	·99
1843—4	15·41	8·86	8·07	..
1844—5	13·11	7·10	11·57	..
1845—6	13·93	9·01	11·50	·28
1846—7	12·93	5·84	11·31	..
1847—8	15·84	8·94	13·00	·70
1848—9	13·49	6·22	13·91	..
1849-50	8·58	1·44	11·82	..
1850—1	14·71	8·49	9·25	·04
1851—2	10·75	3·66	19·97	1·50
1852—3	20·27	10·74	16·79	·24
	249·56	155·43	230·23	9·97
Average of 18 Years.				
	13·864	8·635	12·790	·554
Annual Average.			26·654	9·186

	Winter.			Summer.		
	Rain.	Soil.	Chalk.	Rain.	Soil.	Chalk.
1853—4	9·66	4·22	5·00	9·47	..	..
1854—5	9·32	2·45	3·45	12·66	·19	2·30
1855—6	14·48	6·82	10·47	14·86	2·79	3·09
1856—7	11·96	3·72	7·19	14·11	1·11	1·32
1857—8	11·81	5·64	7·16	12·27	·80	·84
1858—9	9·64	·09	2·69	18·31	..	4·22
1859-60	16·49	9·27	12·44	20·40	3·16	8·94
	83·36	32·21	48·40	102·08	8·05	20·71
Average of 7 Years.						
	11·909	4·601	6·914	14·583	1·150	2·958
Annual Average . .				26·492	5·751	9·872
Average of 25 Years.						
	13·317	7·506	..	13·292	·721	
Annual Average . .				26·609	8·227	

There were various causes which affected percolation, notwithstanding that the amount of rainfall was nearly constant. If there was half an inch, or even three-quarters of an inch of rainfall on one day, succeeded by three, or four fine days, very little percolation took place, even in winter; but if 2 inches of rain fell for two consecutive days, the ground was so saturated, that even in summer, some of the water found its way into the ground. Although, therefore, by considering the amount of rain, and the manner in which it had fallen, an approximate idea might be formed of the quantity of water that had gone down to the springs; yet any notion of forming an average, based upon the rainfall, would be erroneous. During the last few years, an improved form of Dalton's gauge had been adopted. The gauges now consisted of two cast-iron cylinders, 18 inches in diameter, turned to a knife edge at the top, and sunk to a depth of 3 feet below the level of the ground. One of these cylinders was filled with the ordinary surface soil of the neighbourhood, and the other, with ordinary fragmentary chalk; both being covered with grass and the vegetation of the surrounding ground. Any rain that fell, was absorbed by the earth within the cylinders, and if it was afterwards carried off by evaporation, none of it, of course, reached the bottom of the cylinders; but if, on the contrary, any water sank to the depth of 3 feet from the surface, it was collected, and its amount was ascertained in the ordinary manner. It might be argued, that there were causes of error in these gaugings, and that they would not correctly show the absorption of rain, over any particular district of country. It might, for instance, be said, that land which was annually ploughed for the purposes of cultivation, would absorb more rain than land covered with turf; but then it would also part with the water more rapidly, and when the crop sprang up and was growing to maturity, the corn, or other vegetable produce, would absorb a great quantity of moisture. It had been found by experiment, that a blade of corn was able, under favourable circumstances, to absorb much more moisture than its share of the rain falling in any part of this country. Indeed, it would, generally, be able usefully to absorb a greater quantity than it could actually obtain, for it was found by these gauges, that owing to vegetation and evaporation, the percolation in summer was extremely small, compared with that in winter. He thought, that inasmuch as the gauges to which he referred, were covered with grass, the abstraction of moisture for the purposes of vegetation, taken as a whole, was nearly the same as that which took place over ordinary chalk districts. It might be objected, that the depth of 3 feet was scarcely sufficient to prevent the water from returning to the surface; but he thought that depth was quite enough for soil, and if it were not, the only error would be, that the gauges would show a greater amount of percolation, than that which actually took place. It had been found, that the chalk with which one of the gauges was filled, was more absorbent than the soil in the other gauge. Those who lived in chalk districts, and had observed the effect of a shower of rain, could not fail to have noticed how rapidly it was absorbed into the ground. It was rare to see surface drainage in a chalk district; but though the absorption of the chalk was so rapid, he thought, that in these cases, the gauge might, possibly, be deficient, for the capillary attraction of chalk was such, that it always remained moist for a considerable height above the level of the water in the wells. On chalk downs, the vegetation generally remained green during the driest summers; this might, probably, be attributed, in part, to the water being drawn up from the inmost recesses of the chalk, by capillary attraction. The results obtained from these gauges had been confirmed by actual experience. In the manufacture of paper, large quantities of lime were used for boiling the materials, and chalk was burnt for that purpose. It was not dug from a pit in the ordinary manner, but a shaft was sunk, from which headings were driven, as in mining. When the gauges showed the water to have percolated into the earth, he had generally found, after the lapse of one, or two weeks, that it had also percolated into the chalk pit, a depth of 50 feet, or 60 feet below the surface; he could even hear it dripping. But though the gauges showed a certain amount of percolation, he did not maintain, that the flow of the streams in the country, in a given year, was immediately dependent upon the quantity thus absorbed; or in other words, that the volume of water in a stream, was in a direct ratio to the amount of percolation. It was evident, that the streams were the result of the water draining out of natural subterranean reservoirs, formed by the rain which had percolated through the chalk, and which was held up by the impervious strata below; it did not follow, that the whole of it quitted the reservoir in a single year, for he believed it contained enough to furnish a certain outflow for four, or five years, even if there was no rainfall. In point of fact, the water was held in a vessel from which there was a leakage, with a considerable head of water above it. The outflow would depend upon the amount of the head, but it might be a long time before the cistern above was emptied. The level of the water in the subterranean reservoir in the interstices of the chalk, varied in different years, and at different periods of the same year, according to the amount of percolation into the soil; wells sunk into the chalk, would vary as much as 60 feet, or 70 feet, in the head of water. The amount of variation depended, in a great measure, upon the nature of the chalk; in descending from the middle, to the lower chalk and chalk marl, it became less pervious to water. The inclination of the surface of the subterranean store was thus dependent, not only on the amount of percolation, but also on the nature of the chalk. The inclination at which water would stand in the middle chalk, north of London, was, under ordinary circumstances, at least, 13 feet 6 inches to the mile, which was proved by the streams generally running at about that slope. It was evident, that if the water could pass through the chalk with that inclination, it would find its way by some underground passage, instead of by the streams. In its lower beds, the chalk was of a nature to increase the friction, and it would be found, that in the neighbourhood of Berkhempstead, the water stood at an inclination of about 19 feet 6 inches to the mile, and in some parts of Kent and elsewhere, at as much as 40 feet to the mile.

Allusion had been made in the Paper to the River Bourne, at Croydon, which had, for centuries, been regarded as possessing a somewhat mysterious character, but he thought the explanation of the phenomena which it presented, was very simple. He would assume, that under ordinary circumstances, the water that percolated into the chalk, passed through with an inclination of, say 15 feet, or 16 feet to the mile. In years of ordinary rainfall and percolation, the water would, therefore, find its way under ground in a valley, with a fall of 18 feet, or 20 feet to the mile, without showing itself upon the surface; but supposing there to be an excessive supply of water to the reservoir, the inclination of the surface of the reservoir became greater, and a stream would run upon the surface, where there was no stream before. In Hertfordshire, there was a similar Bourne, which was not more than two, or three miles in length. Some years ago, he had it levelled from the point where it joined the river, and the inclination which, as far as he remembered, was from 19 feet to 20 feet to the mile, proved to be within one foot of the calculation he had previously made. He had observed on former occasions, the inclination of the water along the valley of that Bourne, in ordinary years when the stream was not running, and he was thus enabled to judge of the increase of elevation necessary to make the stream visible on the surface. Owing to the excessive rains of last year, that stream had now begun to run.

Another point which had been alluded to in the discussion, was the effect of land drainage upon the streams. He had already remarked, that in purely chalk districts the soil was extremely absorbent, and consequently, no agricultural drainage was required; but in nearly the whole of the district round London, the chalk was intersected by valleys, cutting up what was once, high table-land. In valleys and on their slopes, the soil was light, but the tops of the hills were usually covered with a drift derived from the lower tertiary beds, or with spurs of the lower tertiary formation, and there the soil was of a loamy character, being frequently used for brick making. The percolation of water through such soil was difficult, but still the beds were not impermeable. Those, however, were the only parts of a chalk district which required to be drained; and then, instead of carrying the water down to the rivers, dry, or dumb wells were sunk into the chalk, the absorbing power of which was so great, that it carried away all the water poured upon it, into the subterranean reservoir. In other places, the water flowing off clayey tracts overlying chalk, was absorbed in natural swallow-holes in the same manner.

In answer to a question by Mr. Homersham, Mr. Evans said, that the surface of the soil with which his gauges were filled, was slightly below the knife edge to which they were turned; and he had found the surface soil to be so absorbent, that in the heaviest rains, there was not the slightest overflow.

Mr. R. B. **Grantham** observed, that he should confine his remarks to that portion of the subject with which he was most conversant, and on which he had, during the last session, presented a Paper to the Institution.[1] Sir John Rennie, (Past-President, Inst. C.E.,) with all the authority that attached to his great experience in the main drainage of Lincolnshire, had given an opinion, that pipe drainage was not suitable for that district of country, and that there were many instances in which deposit was brought down in great quantities to the river, by pipe drains, and land drains, rendering it necessary that they should be cleared. But Mr. Grantham maintained, that there was no deposit from pipe drainage; and that there was little, or none, from properly kept drains. Mr. Hawksley, (M. Inst. C.E.,) also, had complained, that particular depths were adopted without any reference to their suitability in each particular case, and that some preferred pipes 1 inch in diameter; others, pipes of 2 inches; and others, tile drains. Now Mr. Grantham believed, that Engineers had not yet given sufficient attention to the whole facts of the case. There were great varieties of practice, and it required considerable experience to know where this system of drainage might be adopted with the best advantage, and where it ought not to be carried out to too small, or to too great an extent. The depth of 4 feet had been established, upon the principle laid down by agriculturists and botanists, that even in stiff clays, the roots of plants would penetrate to that depth. Now if the water was kept at a certain level below 4 feet, the ground above would become more mellow, and warmer for the nourishment of the vegetation. In porous ground, such as sand and gravel, the drains might be placed wider apart, and be carried to greater depths. It might appear, that by putting pipes 4 feet deep into clay lands, scarcely any water would pass into them from above;

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xix., p. 53.

but the real object was, to prevent the cold water below, from rising to the roots of the plants. Pipes, 2 inches in diameter, were the best that could be employed, because part of the area of each pipe was occupied by water, and the other part by air, which was most essential to the nourishment of the plants, and the mellowing of the land, by keeping it at a warm and proper temperature. Valleys were, undoubtedly, occasionally flooded, in consequence of pipe drainage and of the clearing of agricultural land drains, but this was mainly attributable to the existing state of the law, which would not permit of a passage being made through an intervening property, in order to procure a proper outfall. It was well known, that mills, weirs, and other obstructions were causing much injury and harm in agricultural districts; a mill, not worth more than £50 a year, might occasion damage to many hundred acres of land. There were some few instances, however, in which drainage might be carried out to a large extent, and the mills be retained.

He believed a Bill would shortly be introduced into Parliament, with a view to remedy these evils, and the commission which it proposed to create, would be constituted upon the basis of the Inclosure Commission. Every locality would have its conservancy board, and regulate its own affairs, assessing themselves in any way they thought necessary, both for carrying out the requisite works, and for maintaining them.

Mr. **Bateman** was but slightly acquainted with the question of water supply in chalk districts. In the chalk hills round London, the absorption was so great, that there was very little flood water; the rivers were more equable and the springs more continuous, than was the case in other formations. In the hills of Yorkshire, Lancashire, and Derbyshire, which formed the 'backbone' of England, the yield of the springs in dry weather, was from one-half to about three-quarters of a cubic foot per second, for every thousand acres of contributing ground, whilst the flood drainage from the same area, amounted to 200, to 300, and even to 400 cubic feet per second. In the more impervious granite districts, and other primitive formations, there was almost a total absence of springs, and nearly the whole of the water passed off in floods. More information was required on this subject, upon which he had already contributed several Papers to the Literary and Philosophical Society of Manchester.[1]

Mr. **Bailey Denton** remarked, that he found the difficulties of under-drainage, increase rather than diminish. It was said, that it augmented both the drought and the floods; the latter effect could scarcely be doubted, but drought could only be increased by lessening the rainfall, which would, probably, result from diminishing the evaporation. The President, he believed, was of opinion, that under-drainage, on the contrary, promoted evaporation, rather than diminished it. Mr. Denton, however, had satisfied himself, both by experiment and by observation, that although there were not wanting many contradictory facts, that opinion could not be sustained. He had found that, supposing the evaporation from a water surface to be 33, the amount from a saturated surface would be 30, and from a drained surface, about 20. Capillary action might be promoted by drainage, in consequence of the soil down to the bottom of the drains, being reduced to a state of minute disintegration and comminution, thus creating channels of attraction, which brought the water upwards, from beneath the drains. He hoped it would not be inferred, that the water found its way into under-drains, by the upper part, or sides of the drains. Water could only enter from the bottom of the drains; as the soil below the drains must first be replenished by the rainfall before any could run out, and as the water must pass the drain to replenish the subterranean depths, it was evident, that the crust of 4 feet on the surface of drained land, was unimportant in considering the great question of water supply. It had been stated in books of authority, and he believed there was a prevalent opinion, that the amount of evaporation varied from 13 inches to 17 inches, giving a mean of 15 inches per annum. This assumption was contradicted by the fact, that in August, 1859, the evaporation exceeded the rainfall by 3 inches, whilst in the same month of 1860, the rainfall exceeded the evaporation by the same amount, thus making a difference of 6 inches, and showing the incorrectness of considering evaporation as a constant quantity, and the fallacy of quoting means and averages on water questions.

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[1] *Vide* "Memoirs of the Literary and Philosophical Society of Manchester;" Second Series, vol. vii., p. 157, *et seq.*, and p. 191, *et seq.*; vol. ix., p. 1, *et seq.*; and vol. x., p. 137, *et seq.*

His views with regard to deep drainage were confirmed by the inhabitants of the fen districts who were, at the present moment, seeking a lower outfall, in order to increase the depth of their drainage. The opinion prevailed, that under-drainage led to the consolidation of the peat land of the fens.

Mr. G. R. Stephenson remarked, that in another district, there were complaints of the drainage having been already carried to too great a depth.

Mr. Hawksley observed, that out of an average rainfall, near Watford, of 26½ inches, only about 9⅕ inches had been collected into Mr. Dickinson's gauge. Now he had previously stated, that the evaporation in that neighbourhood, had been ascertained to be about 17 inches, on the average, and that it varied from a minimum of 13 inches to a maximum of 18 inches, or 20 inches. Hence arose the inquiry in the Court of Chancery, as to the quantity of water flowing into the River Colne. Hitherto, it had been supposed, that the water which went into the gauge, was simply that which would, under ordinary circumstances, have penetrated into the earth, and have reappeared in springs. But it was now stated, that the edge of the gauge was elevated above the surface of the surrounding soil, so that the 9½ inches of water in the gauge, included both the flood water and the spring water. This explanation reconciled the results obtained by the gauge, with the actual observed yield of the Thames. By measurements made during a sufficient space of time, it had been ascertained, that the amount of rainfall which penetrated the surface, and reappeared as spring water, did not exceed, in very dry years, 5 inches per annum; and in dry summers after long drought, the quantity of water which flowed down the Thames, during the autumn, was only at the rate of about 2½ inches per annum.

He still maintained, that subterranean drainage often had the effect of increasing the magnitude of floods. It had been urged, in opposition to this view, that as the ground became more subdivided, or comminuted by drainage, the rain was more equally distributed through the earth over the drains, and consequently, was more liable to be evaporated, than to flow off in floods, or to pass away by subterranean drainage. This might be perfectly true, under certain circumstances, but when considered under a different aspect, it would be seen, that the opposite result might follow. If this porous and comminuted ground was already perfectly saturated by a recent fall of rain, which was frequently the case in the autumnal months, the ground, being already overcharged, would refuse to absorb any further quantity, which would then run off either from the surface, or by the drains, and the floods would be augmented. That this was really the case was manifest; for recently, many bridges which had stood for ages without injury, had been washed away by floods, and it was an ascertained fact, that latterly, in nearly all districts, from some cause, or other, the floods had greatly increased in volume, and the flow in dry weather had as perceptibly diminished. All water millers concurred in opinion, that the extension of drainage had increased the severity both of the floods and of the droughts.

Mr. Frederick Braithwaite was gratified to observe the unanimity of feeling which prevailed, as to the necessity of procuring an adequate supply of uncontaminated water to the rivers. The laws of absorption and evaporation were in operation over the whole world, but under different circumstances which must be carefully taken into consideration; some were, for the most part, constant; others were fluctuating and variable. In any particular district, the surface of the ground and the nature of the soil were constant, but the extent of moisture in the ground was variable. Some soils absorbed as much as 90 per cent. of moisture, whilst others did not imbibe one-half that quantity. The amount of rainfall was always variable, both with regard to the time and manner in which it fell. The hygrometric condition of the air was likewise subject to many variations; moisture and dryness could never coexist. It appeared from the Tables of Mr. Evans, (Assoc. Inst. C.E.,) that the rainfall, although it might be large, fell so lightly, that it was evaporated almost as rapidly as it was absorbed. The amount of the evaporation was greatly influenced by the velocity with which the air passed over the land. Thus, taking the evaporation over a given space, with a moderate breeze, as 2, it would be, with a gale of wind, 3, 4, and even 5. Under these circumstances, a diversity of opinion was to be expected, as to the actual amount of evaporation, but it had been distinctly proved, that the quantity of water which sank into the ground, was not so considerable as had been supposed.

POLLUTION OF RIVERS, TOWN DRAINAGE AND SEWAGE.

Mr. SIMPSON, (Past-President,) said, it could not be denied, that the Wandle was greatly polluted at the present time; and as the district became more populated, agricultural operations would be extended, and the land would be more highly manured; Collyer's Water and the other small streams would also contribute to the pollution of the lower part of the river. The time, therefore, had arrived, when the evil should be remedied, not only in this stream, but in the other rivers throughout the country. The Wandle was affected to a considerable extent, by the sewage of Croydon, and it had been recently discovered that the gas works of the town drained into the river. In addition to these sources of deterioration, there were others arising from the increase of population in the Wandle valley, the high manuring of the land, and the washing carried on at several of the mills, which frequently rendered the water turbid. He believed, however, that it was possible to exclude three-fourths of the polluted water, and to restore the stream to nearly its original purity.

Sir JOHN RENNIE, (Past-President,) remarked, that the amount of sewage was not constant, but it increased with the growth of the population; the drains were made more direct, and the velocity of the water enabled them to discharge the whole of their contents into the main streams. The latter were being gradually filled with sewage and alluvial matter, and unless proper means were adopted to keep them open, the outfalls would, eventually, be choked up; and during the summer, the nuisance arising from the offensive matter was greatly increased by the heat. The supply of water for domestic and other purposes was thus reduced, in consequence of the deleterious character of the matter falling into certain parts of the streams.

Mr. Gibbs observed, that the pollution of rivers became more apparent as the population increased, and as sanitary improvements were more systematically carried out. The more perfect the drainage, and the more copious the supply of water, the more difficult it became to preserve the purity of the streams. This was particularly exemplified at Croydon, where the sewers of the district were discharged into the river; and no change in the character of the Wandle, could take place, till the sewage was diverted from the river.

Mr. Hawksley said, it was very important to consider the effects of urban drainage upon rivers. In the neighbourhood of populous cities, sewers must of course, be cleansed and drained, and the inhabitants must be provided with all those conveniences requisite for an improved state of civilisation; but he denied, that it was invariably necessary, in so doing, to injure the rivers by the introduction of the sewage. The River Wandle was an instance of a river being polluted, almost without necessity. In the valley of the Wandle was situated the now large town of Croydon, which, with its neighbourhood, contained not less than thirty thousand inhabitants. The municipal authorities of that town had constructed, properly enough, a net-work of sewers; but the sewage was, eventually, permitted to run into the river. It was said to be deodorised, but the process of disinfection which had been used was insufficient to accomplish the object. In this state, it was turned over the land for the purpose of irrigation, whence it was allowed to run into a stream communicating with the main river. The result was to create a stench, which could only be compared to that of the meadows near Edinburgh. Now there was no necessity, that this state of things should continue: if the local authorities expended the proper amount of money, there were several means by which foul water might be prevented from polluting the river. The works for that object, erected at Leicester, by Mr. Wicksteed, (M. Inst. C. E.,) although not commercially remunerative by the sale of the manure, effected the purification of the sewage water, which flowed perfectly clear into the river. When the undertaking passed into the hands of the municipal authorities, they diminished the quantity of deodorising material, and the water, consequently, was not so well purified now, as when the works were in the hands of the company. The expense, however, was not inordinate, as the experiment was made at an original cost of £40,000, and an annual outlay of £2,500, (since reduced about one-half,) which was an insignificant sum for a population of seventy thousand inhabitants.

There were two modes of employing sewage water with a view to its beneficial application; by allowing it to flow by gravitation over lands, situated on a low level, and by pumping it from tanks over large areas of elevated lands. But the first system could not be applied usefully and economically, to the irrigation of land near large towns, because the sewage would have to travel a considerable distance in the urban sewers, and through prolonged outfalls, during which course the valuable fertilising matter became oxidised, and was therefore, almost, if not entirely, valueless for agricultural purposes. The attempt had always failed, near large towns; but near small towns, where the sewage water could be applied fresh, and whilst containing all the undecomposed manure, it became a valuable fertilising agent, when spread over the land. But precisely on account of its value it became a nuisance, unless previously deodorised. Experience had proved, that McDougal's fluid effectually accomplished this object, when applied in sufficient quantities; it, moreover, was cheap, as one gallon, which cost 8*d.*, would purify from 12,000 gallons to 15,000 gallons of sewage water, according to its strength. This fluid was the second product of distillation of gas tar, at a low temperature. In the first distillation naphtha was produced; in the second, a fluid which, being rendered alkaline by a little quicklime, possessed the deodorising power. This was the process pretended to be adopted at Croydon, but an insufficient quantity of the fluid was applied, as was manifest from the fact, that the matter from the sewage water deposited on the fields, emitted the most sickening odours. McDougal's fluid, though an invaluable deodoriser, was, however, inimical to fish and other animals living in water.

The second method of purifying the sewage was, by pumping it from tanks, over large elevated areas; but the cost of that system was so great as to prevent its application. It might, possibly, answer with a small quantity of water, but if it was requisite to pump millions of gallons daily, and to economise it in wet weather for use in dry weather, the arrangements necessary for giving commercial value to the water, would never be remunerative. It had been tried, among other places, at Rugby, the capital being found, partly by a private gentleman, and to a limited extent, by the town. But the result had been unsatisfactory, the value of the improvement to the land being, as nearly as possible, the sum expended in manipulation. The whole of the sewage was not used on the land, a considerable portion passing through strainers into the river. The pumping system could not, therefore, be recommended as a remedial agent at Croydon, where, he believed, it had been proposed by Mr. Shepherd.

Much misapprehension prevailed as to the increased value of land irrigated by sewage. An example had been cited near Edinburgh, in which land not worth £1 per acre had, from the application of the sewage, become worth £25 per acre. But it was the proximity of the land to the city, which had so much increased its value, and which had enabled the sewage to be made available upon it; guano would have rendered it as fertile as the manure from the sewage. If the sewage could be put upon similar soil in the Highlands, it would not increase the value of the land one-tenth of that amount. He could mention other instances of land thus manured, fetching as much as £60 per acre, but it was the proximity to large towns, and not the sewage, which had so considerably increased its value, for any other proper agricultural stimulant, rightly applied, would produce the same results, without the nuisances which usually resulted from irrigation with sewage water.

The main question, however, was, what means could be taken to restore the Wandle, which was becoming daily more polluted, to nearly its pristine condition. A great number of manufactories were established on its banks, on which there were also many large and valuable properties, the owners of which were, generally, not interested in the adjacent mills, or manufactories. The rights of these proprietors ought and could be preserved, by instituting a proper conservancy for the purpose. He believed it could be effected by a combination of private individuals, and that there was no necessity for making that application to Parliament which had been proposed, under the name of conservancy, but the object of which was rather to destroy existing rights, than to maintain them.

Mr. HOMERSHAM said, that in the autumn of 1857, he had personally examined the system of deodorising the sewage, employed at Leicester, and from the returns furnished to him by Mr. E. L. Stephens, Engineer of the Borough, he had ascertained, that out of thirteen thousand houses, only seven hundred were connected with the sewers of the town, and that the fæcal matter from only that number of houses went into the reservoir, where the water was deodorised. The town was plentifully supplied with water both from the water company and from private wells, and the surface drainage of the streets was allowed to run into the sewers; it was not surprising, therefore, that when so small an amount of fæcal matter entered the deodorising tanks, the water should come out moderately clear. A large portion of the quicklime used to deodorise the sewage was, necessarily, converted into chalk, the water supplied by the water company, being of 16° of hardness, and containing much bicarbonate of lime. The greater part of the fæcal matter of the town, did not enter the sewers, but it was mixed with ashes at the various middens, and was conveyed away in carts. At Croydon, on the other hand, there was scarcely a house without one watercloset, and many with two, or three, all connected with the sewers. It was important, therefore, in instituting a comparison between the two towns, to bear in mind the different quality of the sewage matter.

Mr. FENTON thought, that justice had not been done to the

Croydon Board of Health, under whose direction he had carried out, without restriction, the present works, no expense having been spared in purifying the sewage water. The correctness of the principle adopted, that of applying McDougal's fluid, in the first instance, and then passing the water over the land was not denied, but it was asserted, that too little fluid was used. He had diminished the quantity of fluid, in consequence of the perceptible smell of tar at the outfall, when one gallon of fluid was applied to 20,000 gallons of sewage water. He had reduced the proportion of fluid by one-third, and even now, there were occasional complaints arising from the same cause. He should be glad to know, at what point the inspection had been made to which Mr. Hawksley had alluded. The Croydon Board was always ready to carry out any sanitary measures that could be proposed, and the expense had not been, and never would be, a matter of consideration with them. All were agreed, that sewage water could be purified, and that the rivers of this country ought not to be polluted by it.

In answer to inquiries by the President, Mr. Fenton said, that the sewage of Croydon was carried, at present, over about 60 acres of land, and that a very small proportion of fluid was used during the cold weather. He had found no smell at the outfall, and the water was quite pure. The quantity of fluid was not diminished from economical considerations, but on account of an intimation from some of the owners of the mills and fisheries on the stream, that they thought the tar was injurious to the fish. If it was thought desirable to use a larger quantity of fluid, he would undertake to say, that the Board would, at once, order it. He would not like to apply the sewage to the land, without first straining off the solid matter, and afterwards, in warm weather, deodorising the water; it would, otherwise, create a nuisance, which, in hot weather, would be unendurable.

Mr. Rawlinson disputed the correctness of the remarks that had been made, concerning the irrigation of the Craigentenny meadows, near Edinburgh. The proprietors denied, that the extraordinary value of the land, which had risen from £15 even to as much as £45 per acre, was caused by its proximity to the city, but they asserted it to be due to the effects of the sewage placed upon it. A considerable portion, previous to the irrigation, consisted of sea sand, and on pulling up the grass, the sand was still to be seen, covered only with manure, about an inch in depth, attached to the roots. If the irrigation were discontinued during twelve months, the land would become worthless. As to the proximity of large populations giving value to the land, there was in the neighbourhood of Edinburgh, as also of London, and of most other large towns in Great Britain, grazing land of the richest description, for which not more than £5, or £6 per acre could be obtained.

The composition of McDougal's fluid had not been correctly described; it contained a good deal of lime, and but very little carbolic acid. He believed, however, that during nine months of the year, it was not required. If the sewage was placed fresh upon the land, it would be disinfected, without the intervention of any deodorising mixture; it was the putridity that caused offensiveness, and putridity resulted from age. As a member of a commission appointed to inquire into the subject of the pollution of rivers, he had, in the course of his duty, examined nearly every stream in England that was polluted by sewage, and on which sewage works of any magnitude had been carried out. It was, undoubtedly, an evil that called for remedy, but he did not think, that it could be effected by such a conservancy of private individuals as had been proposed. He did not see how any national system of conservancy could be instituted, without the initiation of the government, or without centralisation in some form. It might consolidate powers, make them permissive, or hand them over to local authorities, as was generally the rule, but there must be a central official head. The Wandle was purity itself, compared with the rivers which flowed through the Lancashire and Yorkshire manufacturing towns, and which were foul from their sources to their estuaries. He contended, that the first consideration of a civilised community ought to be human life and health, for it was that, after all, which gave value to property. That object must be effected, even at the risk of private injury to individuals, by partially killing their fish, or partially damaging their ornamental grounds; but he firmly believed it could be accomplished, without the annoyances which had been so much complained of.

Mr. John Evans said, it had been suggested, that main drains should be constructed alongside the rivers, but it seemed to him, that if all the water that was now employed by the towns situated upon rivers, was permanently diverted from them, the supply would be so diminished, that the rivers themselves would become not only useless, but pestiferous. Then again, if the water was to be returned to the river, after it had been used for the various purposes of the town, it appeared there were very great, not to say insuperable, difficulties in restoring it in such a condition as not to be injurious to the river, and to the health of those residing near it.

The production and utilisation of sewage might be regarded as a manufacturing process. Sewage matter as originally produced, was, no doubt, a most valuable product for agricultural purposes; but if a manufactory were established to produce manures of various kinds, it would be thought absurd to dilute them with water to such an extent, so as to make them undergo fermentation, and thus render them comparatively useless. The question to be considered was, whether those matters which were produced in a solid form, could not be preserved in that form, so as to retain their value as fertilising agents. What seemed to be required was, some intermediate course between the old cesspools and the modern system of waterclosets and sewers. He could not point out a method by which this could be effected, but any one who could find a means of retaining the sewage matter for manure, and at the same time, of restoring the water to the rivers in nearly its original purity, must be regarded as a benefactor of mankind.

Mr. W. DRUMMOND, the Chairman of the Croydon Local Board of Health, observed, that there was a remarkable circumstance connected with the Wandle, celebrated as it was for its trout and for its beauty, that at the head of it, at its very urn, there should be a town containing, as it had been stated, thirty thousand inhabitants. That statement, however, was not strictly correct; the parish, indeed, contained that number, but in the town, there were only twenty thousand; and the locality inhabited by the others had its watershed elsewhere, and its drainage had nothing to do with the Wandle. When the Croydon Local Board of Health was established, ten years ago, and previously to that time, no effort had been made to keep impurities out of the river. The usual position for the privy of a cottage, was over one of the streams feeding the Wandle, and there were hundreds of these cottage conveniences. There were in the town, two large ponds, each about half an acre in extent, with copious springs in them; but these ponds served as two large cesspools for the sewage of the town, and they were choked with black mud, to a depth of from 2 feet to 5 feet. When the Board of Health undertook the drainage of Croydon, the river just below the town, was foul with deposits of offensive mud, on each side of the stream, which meandered through these banks of filth. It was the object of the Local Board, not merely to drain Croydon, but also to purify the Wandle, which was much esteemed as an ornamental and interesting feature of the neighbourhood. He mentioned this desire of the Board, because the labours of the Croydon Board of Health, had been unfavourably alluded to. They had been accused of devoting too much time to mere talk, but so little vanity did they possess on that score, that during the first five years of the Board's existence, the members had persisted in excluding from their meetings, the reporters of the public press. They had also been accused of parsimony in using too little disinfecting fluid with the sewage. The Board, however, laid no restriction in that respect on their surveyor, and they were disposed to spare no expense to prevent the pollution of the Wandle.

The problem which the Croydon Board had before them, was this: a population of twenty thousand being at the head of a river, with no other outfall, or means of drainage, what was the best mode of dealing with the sewage? It was a problem now before the public, 'coram judice,' and which could scarcely be said to be yet solved. But the Croydon Board had laboured hard to solve, in practice, this very important problem, and they were, moreover, at all times, ready and anxious to receive the suggestions of scientific and of practical men; and he firmly believed the result to have been, that no other inland town was better drained, and the sewage disposed of, with less inconvenience to the neighbourhood. Formerly, there was no arrangement whatever, either for purifying the sewage, or for keeping it out of the river, which was the general dust-bin, sink, and sewer of the town. In fact, it was customary for the millers periodically to plough the bed of the river, in order to clear away the obstructing mud. At present, the sewage from four thousand houses was entirely intercepted. The whole, including the outpourings from a tan-yard, and from a street of butchers, was now received into glazed pipe sewers; it was there largely diluted with an abundant supply of water, and within an hour after any foul liquid was generated, it was carried, by these pipes, to a distance of two miles from the town. Not a particle remained to generate unwholesome gases among the inhabitants, and the river now, from the town to the first mill, ran sparkling and clear, and it was unpolluted by the population at its source. The sanitary condition of the town was greatly improved; the deaths were now only 16½ per 1,000 per annum, while the average for the previous ten years, was 20 per 1,000, and before the operations of the Board, it was 22 per 1,000. The sewage was conducted through fields, away from the river, till it came by gravitation, to a farm of 96 acres, belonging to the Board of Health, where it underwent three processes. First, it was strained through filters of gravel to remove the solid matter, about 20 tons per week, of rich manure being obtained, consisting almost entirely of night soil, not too much washed with water, to be deprived of its fertilising qualities. This met with a ready sale at one shilling per ton, the object being to get it promptly removed, rather than to make a profit by it; in three weeks, as much as 800 tons had been sold, for which £40 had been received. Having thus deprived it of all the solid matter, the sewage was then, in warm weather, mixed with as much as was necessary, or useful, of McDougal's fluid. On one occasion, so much of that fluid had been used, that the water at the outfall, after going over the farm, retained a perceptible odour of tar, of which the fluid was a distillation. Since then, a less quantity had been applied, and in the winter, none at all; yet there was no perceptible odour. He was satisfied, that the abominable smell, which had been so much complained of, did not proceed from the farm; it must have been at some spot that had no connection with the drainage works. The sewage water was, subsequently, made to flow over and through the grass and land of the farm. The reason why this occasioned no offensive smell in the fields, and why so little disinfecting fluid was requisite, was, that the sewage was all recent and was much diluted. It was only an hour, or two hours old, and it was diluted with a quantity of water equal to 200 gallons per house per day. So long as the sewage was put fresh upon the land, it emitted no offensive odour; the odour only became repulsive and unwholesome, when it was allowed to stagnate till putrefaction set in. As the sewage reached its destination in about an hour, it did not require so much fluid as was supposed to be necessary; but a much larger amount would be required in dealing with the sewage of London, which had tarried in cesspools and loitered in its sluggish course, till it had begun to ferment. The result of sending the sewage over the grass land was, that the crops were largely increased, and that the water flowed off clear and pure, both in taste and smell. The Croydon Board, therefore, were doing all that could be done, in the present state of knowledge on this subject, and should not, therefore, be blamed, or disparaged. If any superior mode of dealing with the sewage of four thousand houses could be pointed out, he could promise, on the part of the Croydon Board, that it should, at any cost, be adopted.

Mr. Bailey Denton had, recently, an opportunity of examining the value of 'clear water.' He was called upon to decide, whether an order of the Court of Chancery had been duly carried out, in the case of Barnard *v.* Arkwright; and on that occasion, he had the assistance of Professor Voelcker, consulting chemist of the Royal Agricultural Society. The order of the Court was peremptory, that no pernicious water from the cleansing of certain dog kennels, and of the larders appurtenant thereto, should be allowed to flow into the stream at Harlow. Mr. Arkwright was the master of the Essex fox-hounds; and it appeared, that a practice existed of cleansing the dogs with some kind of arsenical preparation; that the dogs, moreover, were occasionally fed with the flesh of glandered horses, and that the water of the stream which received the drainage from the kennels, was impregnated to an injurious extent, by those two ingredients. On investigation he found, that Mr. Arkwright had constructed filter beds, and had adopted a variety of other contrivances, so that the water flowing from them, was perfectly clear. Professor Voelcker put some of this water into bottles for analysis, and when after two, or three days, it was uncorked, it emitted an insupportable odour.

Mr. Haly had been associated with several eminent Engineers, in inquiries which involved the whole subject of the pollution of rivers. In fulfilment of their duties, the Commissioners visited nearly every place in England, at which attempts had been made to purify the sewage, and they had found, that at Croydon the question of sewage irrigation was still far from solution. To an unprofessional mind, there was little difference between sewage and any other manure, such, for instance, as guano. But there was no relevancy whatever between liquid sewage and guano in a solid state; nor between sewage as it issued from the sewers, churned and pounded up, and subjected to the action of water and of the atmosphere, and the liquid manure of the farmyard tanks. This point had been admirably argued, in the following extract from a Report signed by several distinguished Members of the Institution:—

"From the results of our own practice and experience in hydraulic engineering, and particularly in reference to the drainage of towns, and the utilisation of the products of sewage, we have long been aware of the important fact, that those organic matters which are commonly received from the domestic drains into the street sewers, and are there acted upon by water and air, undergo changes and decompositions, not necessarily of a putrefactive character, but in the course of which, they either become resolved into their original elements, or become combined into new forms, essentially different from those in which they originally existed. These changes are effected with great rapidity,—so much so, indeed, that it is rare to find in the waters discharged from the sewers of a large town, any of those fertilising agents it has been the object of so many endeavours to obtain; fertilising agents of a class which, if they could continue to exist and act in combination with flowing water, as they observantly exist under other circumstances, would engender nuisances of a character most prejudicial to health and intolerable to the senses."[1]

The contents of the sewers being thus shown not to possess a fertilising character, it was only left to consider, whether by any known process, they could be made to assume a commercial value. The processes hitherto tried, might be divided into two classes; the solid and the liquid. As the best possible illustration of the former, he would instance the sewage works at Leicester, where they had a Local Act in their favour. The works were situated in a town which, like Croydon, was extremely rich in its sewage products, which possessed the same advantage of being brought down fresh to the works. At Leicester, the sewage was not much diluted with water, but it was mixed with oily and fatty matters, from the woollen manufactures and the wool-combing so extensively carried on in that town. There were peculiar local advantages, therefore, for obtaining the sewage of that important town, in a condition capable of being turned to profitable account. The local authorities, as at Croydon, were not seeking to make a profit; all they required was, that the river should be saved from pollution, by a system of deodorisation, and the separation of the solid from the liquid matters. In these respects, there could be no doubt, that the works at Leicester had been successful, and that the requirements of the Local Act had been carried out. The water was let off into the stream in a comparatively pure state, but the large quantities of débris which were obtained by the lime process, could not be disposed of. At Croydon, it appeared, that it found a sale at a shilling per ton, but at Leicester, there were, when he visited it, between 6,000 tons and 7,000 tons, in the shape of bricks, which no one would cart away for manure, and which were piled up round the works, polluting the atmosphere. In fact, a profit could not be realised by the manufacture of solid manure from sewage.

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[1] *Vide* "Report of Messrs. Bidder and Hawksley to the Metropolitan Board of Works, upon the Main Drainage of the Metropolis." London, 1858. Page 66.

As an illustration of the liquid process, he would cite the works, established several years ago, at Stanley Green, under propitious circumstances, for they were favourably noticed in the Report of the General Board of Health, and they were even carried out under the auspices of that department of the Government. Their promoters first tried the solid process and failed. They then tried the liquid process, being placed in an advantageous position for the experiment, as the works were situated in a suburb of London, from which the drainage was obtained with comparatively small admixture. A large tank was provided, as at Croydon, from which the mixed fluid and solid matters were poured upon the market gardens in the vicinity. But the gardeners objected to its use, and the demand for liquid manure not proving equal to the supply, the works were closed.[1] Croydon afforded another illustration of the

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[1] *Vide* "Report of Captain Galton and Mr. Simpson, on the Main Drainage of the Metropolis," Appendix XII., page 476. Minutes of Evidence given by Mr. G. E. Lane, late of the Stanley Bridge Sewage Works, 13 May, 1857.

"Mr. Lane stated, that the Metropolitan Sewage Manure Company's Works at Stanley Bridge, near Walham Green, with which he had been connected, were now suspended.

"Mr. Lane found the sewage, applied in a liquid state, very good for plants; when applied to the roots, it was good in every respect, but sometimes when applied from above, the leaves got covered with scum, and this was injurious to the plants.

"The reason the Company had suspended operations was, that the persons who used the liquid, failed to pay for the use of it, and the concern altogether was unprofitable.

"Mr. Lane said, that complaints were made to him of the works being a nuisance, but were never officially laid before the Company.

"Mr. Lane stated, that the pipes got so firmly charged with solid matter, (compressed manure,) that it was impossible to clear them, when taken up after the stoppage of the work, without the use of sledge hammers.

"The liquid sewage had been applied to a strip of grass land, with great success; the grass was, however, very rank and coarse.

[" Mr. Lane

liquid process. When he visited it in 1858, there was a large space of ground over which the sewage had been poured, from which a powerful odour was emitted. At the period he referred to, there was a great accumulation of solid matter, which created an insufferable nuisance, for which he believed the promoters were indicted. Croydon had been, at one time, the seat of considerable disease, which was generally attributed by the medical profession, to the existence of these works. In the Report of the Earl of Essex and his brother Commissioners, in 1858,[1] it had been laid down, that malaria might be induced by open sewers conveying liquid manure, but that it would be prevented by passing the liquid through pipes and applying it to the land by the hose. Within the last two months, he had visited the works at Watford, from which the Earl of Essex obtained the liquid manure which he applied to his home farm at Cashiobury. At the Watford works, the sewage was accumulated in a tank at a low level, and it was then pumped through pipes for a distance of nearly two miles; but although it was applied to the land at Cashiobury, under the most advantageous circumstances, the undertaking was not commercially successful. The grass produced was of a rank character, and the works themselves were a nuisance to the neighbourhood.

He should now refer to the great case, invariably cited by those who favoured sewage works, that of the Craigentenny meadows, which had been subjected to the process of sewage irrigation, for sixty years. These meadows received their supply from the sewage running immediately out of Edinburgh, upon what was, formerly, waste land, and the plan had been, so far, commercially successful, that a very large amount was derived from the grass produced. This success, he believed, was to be accounted for; first, from the fact of the land being of no intrinsic value; secondly, from its peculiar position, which enabled it to be cultivated by a process which brought the soil to it, in its cheapest form; and thirdly, from its being possible to sell the grass to great advantage, in the city of Edinburgh, where milch cows, kept in stalls, were fed on the produce. Almost any waste land on which soil could be poured, would produce grass, and if that

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"Mr. Lane stated, that the operations at the works had been suspended some time, and all the pipes taken up.

"Upwards of £40,000 had been spent in the concern, and he considered it altogether a failure."

As to solid manure:—

"The manufacture of the manure for sewage with peat charcoal, sulphuric acid, &c., was so expensive that it could not be made profitable."

[1] This Report was signed by the Earl of Essex, H. Ker Seymer, (M.P. for Dorsetshire,) Robert Rawlinson, (Assoc. Inst. C.E.,) J. Thomas Way, J. B. Lawes, T. Southwood Smith, J. Simon, and Henry Austin. It is dated, "13 Great George Street, Westminster, 26 March, 1858."

land was in the immediate vicinity of a large city like Edinburgh, such grass could, no doubt, be sold so as to realise a profit. He would, however, read a short extract from the Report of the Earl of Essex and his brother Commissioners, as to the effect of the system upon the health of the district:—

"There is one circumstance in the case of the Edinburgh meadows, which is invariably brought forward as an objection by the opponents of sewage manure, namely, that they give rise to constant complaints, not only from persons living in the immediate neighbourhood, but from inhabitants of some parts of Edinburgh itself, at a distance of two miles. There can be no doubt that, in their actual condition, they would be a source of nuisance, especially in hot weather; but we feel satisfied, that this evil is not a necessary concomitant of sewage application, even in the large quantities employed at Edinburgh, but that it arises from the existence of open ditches which convey the sewage, and on whose banks, solid, offensive matter is deposited and exposed to the air."[1]

This was precisely analogous to the state of things at Croydon. In both cases, it appeared that a nuisance was created, and it was alleged, that the system was injurious to health. If there was any doubt upon the subject, he would take the only remaining case of open liquid sewage irrigation that was said to be successful, that of the city of Milan, where the sewage of a large city was poured, under favourable circumstances, upon the meadows in its vicinity. Lord Essex's Commission sent a deputation to Milan, to inquire and report upon the sewage irrigation of the land around that city. Amongst others, the Commissioners examined Dr. Antonio Capelli, a leading physician of the city of Milan. The following was quoted from his evidence:—

"Have you observed any influence on the health of the inhabitants, from this use of the ground?—A most decided one.

"In what respect has it acted injuriously on health?—First, in producing every kind of ague; secondly, in producing the other forms of disease due to marsh miasma, such as neuralgia, rheumatism, chest inflammations, (pleuritis), &c.; thirdly, in sometimes producing pernicious remittent fever, which often kills in a few days.

"Are such diseases frequent?—Very frequent indeed.

"Is the health of infants and children more especially affected?—Yes, most especially, as is shown in the unusual prevalence amongst them, of scrofula and rachitis.

"You have stated that the condition of the houses has, in some degree, an unfavourable influence on the health of the inhabitants, from the want of proper means of disposing of the house refuse, from want of light and from dampness; do you suppose that these circumstances act by increasing the susceptibility to malaria, or in what other way?—If these conditions were entirely absent, if the houses were of the best kind, the people would be affected in the same manner, though, perhaps, in a less degree. These unfavourable circumstances do exert some influence in increasing their susceptibility generally; but those who live in the best houses in this neighbourhood, and who are comparatively rich, are by no means exempt from the influence of the malaria; on the contrary, they feel it sensibly.

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[1] *Vide* "Report of the Sewage of Towns Commission," page 15; signed as quoted in note, page 243.

"Then, is the result of your observation and experience, that the diseases you have named are produced generally, wherever irrigation is carried on close to human habitations?—Everywhere; it is so inevitably."[1]

He would now read the conclusions arrived at by the Commissioners, who had so laboriously investigated this subject. He would first quote the Report of the Government Referees appointed to consider the Main Drainage question, dated the 31st of July, 1857, and signed by Captain Douglas Galton, (Assoc. Inst. C.E.,) of the Board of Trade, Mr. James Simpson, (Past-President Inst. C.E.,) and Mr. Blackwell, (M. Inst. C.E.,) who were fortified by the Chemical Reports of Dr. Hofmann and Mr. Witt. Those Commissioners reported as follows:—

"That the so-called deodorisation of sewage does not remove the highly putrescible, soluble constituents from the liquid which passes off; and that consequently, the liquid, after deodorisation, must be disposed of in the same manner as ordinary sewage water.

"That we do not believe, that the deodorisation of London sewage could be carried on without creating a nuisance; and that no plan would be effectual with the increased volume arising from rain.

"That the value of the fertilising matter contained in London sewage is undoubtedly great; but that the large quantity of water with which it is diluted, precludes the possibility of separating more than about one-seventh part of this fertilising matter, by any known economical process.

"That a copious dilution of the sewage is necessary to health, and that therefore, the sacrifice entailed by the dilution must be endured."[2]

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[1] *Vide* "Report of the Sewage of Towns Commission. Dr. Capelli's Evidence." Pages 50, 51.

[2] *Vide* "Report of Messrs. Galton, Simpson, and Blackwell to the First Commissioner of Works." (Presented to the House of Commons, September, 1857.) Conclusions. Page 43.

That was the Report of the Government Referees. The Report of the Engineers appointed to consider the question by the Board of Works, fortified as it was by the Report of Dr. Letheby, was even more decisive. They reported thus:—

Utilisation of Liquid Sewage.—"We have been compelled to consider this question, and being personally acquainted with most of the practical applications of town liquid, as at Edinburgh, Mansfield, Rugby, Croydon, and other places, come to the following conclusions:—

"Firstly. That the fertilising properties of the organic matters contained in town refuse, are, for the most part, destroyed by the long-continued action of water.

"Secondly. That the cost and difficulties attending the application of liquid sewage, in large quantities, are absolutely prohibitory of its use.

"Thirdly. That liquid sewage cannot, in general, be used with advantage in this climate, except in particular states of the weather, and in certain stages of the growth of the crops to which it is applied.

"Fourthly.- That, commonly, the distribution of liquid sewage is accompanied by a noisome odour, and except in the case of its application to sandy, or rocky soils of considerable inclination, is liable to induce the worst forms of marsh malaria."[1]

Those were the conclusions for which he contended. He felt that nothing he could say, could add to their force, and he would, therefore, conclude by commending them to the attentive consideration of the Meeting. It was his earnest hope, that Civil Engineers would endeavour to prevent capitalists from embarking in sewage speculations which, whilst they began in delusion, must inevitably end in failure. For their own sakes, he urged, that it was most desirable, that this question should be treated on its real merits, for so long as the leading inhabitants of provincial towns supposed, that sewage works of some sort might, hereafter, be commercially productive, so long they would postpone effectual remedies for the improvement of their drainage. Finally, he committed the question to them in the most entire assurance, that it would be determined in the way that would be, at once, most beneficial to the public, and most honourable to the profession.

Mr. Rawlinson, having been connected with the former Board of Health, could state, that no member of that Board had, in any way, patronised, either by becoming a shareholder, or otherwise, these irrigation works at Fulham. He had examined the works himself, and so far from approving of them, he stated his belief, that they could never prove commercially successful.

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[1] *Vide* Report of Messrs. Bidder and Hawksley. Additional Observations. Note B. Page 145.

Mr. C. GREAVES was in a position to state, that the Metropolitan Board of Health had no connection with the Fulham works, either as directors, or proprietors. Those works were established, in 1846, by a company, who, at the outset, expended on them a capital of nearly £50,000, from which they had never received a single dividend. Not more than one hundred acres of land were watered at one time, nor was the system extended to more than 150 acres; and probably, the Company never received, altogether, more than £500 for rent. That project, therefore, ended in decided failure; but he did not necessarily infer, that the application of sewage manure was a failure, for there were many reasons why it should not have succeeded in the case in question. The Bill which constituted the Company, was strongly contested in Parliament, and when, after considerable expense, it was, eventually, obtained, it was found to contain many penalties and to confer but few privileges. It was, originally, intended to take the sewage from the Ranelagh and King's Scholars' Pond sewers, at Pimlico and at Knightsbridge; but difficulties arising about the purchase of land, the Company afterwards obtained an amended Act, enabling them to abandon a portion of the works. They then proceeded to construct the works at Stanley Bridge, and they began the operations upon a much more limited scale than they had, at first, proposed, abandoning their intention of pumping the sewage from Knightsbridge, as well as that of conveying it to Bagshot Heath. As carried out, the works consisted of the erection of a steam engine of 40 H.P., with a standpipe and complete apparatus, at the Counters' Creek sewer, the water of which was neither strong, nor of a fertilising nature, whence it was pumped upon the market gardens in Fulham Fields, which consisted of an area of between 800 and 1,000 acres. A main, 16 inches in diameter, was laid through the principal streets along the route, the size being reduced by branch pipes, as it approached Fulham. But the whole system was badly conceived from the commencement, and difficulties were encountered at every step. In the first place, the sewage water was not strong, and it had the appearance of being of less value than it really was; so that the gardeners had no great desire for it. The idea of pumping sewage, and delivering it at a distance, after the manner of a water company, through miles of pipes, was perfectly impracticable; the cost of working was so great, that the scheme could not be remunerative. After the works at the Counters' Creek sewer had been in operation for about twelve months, and after Mr. Greaves had undertaken the management of the engineering department, he obtained the permission of the Commissioners of Sewers to make a connecting sewer, so as to intercept the sewage from Knightsbridge, by shutting a pair of large gates in the Ranelagh sewer;

and the sewage from Paddington was thus forced through the Company's sewers and pipes to Stanley Bridge. From that time, the sewage was stronger, and was, probably, as rich as any that could be found; and the farmers did not complain of it. But there were other difficulties to contend with; the stench from the sewage was so strong and pernicious, that no one could remain in the engine house, for any length of time, except those who had long been accustomed to it; and it was not easy to obtain clean water for the condensers and for feeding the boilers. The grit, also, that came with the sewage, was a source of great inconvenience; it destroyed the valves of the pumps, with extraordinary rapidity, and when the pipes were afterwards taken up, the main, 16 inches in diameter, was found to be half filled with sand for the first half mile, and even beyond that distance, the pipes were choked to a considerable extent. Great difficulty was experienced in preventing the deposit of fine matter in the distribution pipes, and considerable pressure had to be applied to force the dirt through them, the farmers being often unwilling to receive it. Then again, the orifices for the distribution, for which ball valves were used, were tampered with, when the pressure was off. The destruction of hose pipes was also enormous: upon an average of twelvemonths, a hose lasted only seventy days; and in some cases, it did not last a month. Owing to the sewage being largely impregnated with salt, it was impossible to dry the hose, and the cost of that article alone, was more than the rent received from the farmers. The Company had been misled by some fancied analogy with the system employed at Edinburgh, which was a case widely different from that which they had undertaken. There, the sewage was brought down to the meadows with scarcely any cost, in a small channel, by gravitation, after the manner of ordinary meadow irrigation, and in some cases, it was distributed over the land in little trenches. By merely cutting a sod, the required quantity of liquor was obtained, and the supply was as easily cut off; the surplus, which was not wanted, escaping to the sea.

In answer to a question from the President, Mr. Greaves said, that it was the opinion of some of the market gardeners, that no benefit whatever was derived from the sewage; but there were no exact means of arriving at any definite conclusions on the subject. In many cases, the crop was, no doubt, benefited by the mere watering, without respect to the sewage. He remembered an instance, in which the water was applied for, to moisten the soil, which had become so hard, that the gardener could not pull his crop of radishes. But it was very evident, that the benefits were not sufficient to remunerate an extravagant outlay and an expensive system. In situations where the expenses would be less, or where any crop that might be forced, bore a fictitious, or unusual value, he had little doubt, that the process of irrigation with sewage water, might be profitably worked.

Mr. HAWKSLEY admitted the correctness of the statement, that although the population of Croydon was thirty thousand, yet that part of it was outside the drainage of the Wandle. That, however, did not affect the point at issue, which was, that the Local Board of Health had constructed sewers, which had the effect, not only of receiving the drainage from the town, but of intercepting some of the springs, and of carrying off a large quantity of water, very nearly 2,000,000 gallons per day, which would, otherwise, have passed into the river in its pristine purity, and at a higher point than the outlet of the sewage. That water, mixed with the ordinary sewage of the town, was conveyed to the deodorising works, where the solid matter was roughly strained from it, and it was then delivered, by channels, over about 90 acres of land. The land over which this water was distributed, was very flat, and the edges of the channels which conveyed it were, in places, slightly raised by the earth. The upper portion of the soil was, to a certain extent, aluminous; but the lower portion consisted almost entirely of coarse chalk gravel. The result was, that the surface of the ground was flooded by means of the channels, only to a limited extent, and the larger portion of the water penetrated into the gravel, so that when the ground was trodden upon deeply, it oozed upwards, into the hole. The consequence was, that the vegetation was partially destroyed, and that the sheep put upon the land had become affected with foot rot, in numbers sufficient to demonstrate the unhealthiness of the ground. The water, moreover, was draining underground into the neighbouring property, where the hedgerows and the timber trees were already beginning to suffer. Having been into every field upon which the water was delivered, he could declare it to be an offensive nuisance; at any rate it was so last autumn, and he knew a gentleman who had been compelled, for that reason, to remove his family. As a specimen of irrigation and application of sewage manure, the result was as bad as could be imagined. It was difficult to ascertain exactly, all the facts of the case. It appeared, that the Board of Health originally turned this water, some years ago, upon the land, under the idea that it would improve it; but the occupiers were so convinced of the mischief which it occasioned, and of the nuisance it created, that some of them took legal proceedings to recover damages. Therefore, the Board thought it more expedient to take the land into their own hands, and consequently, it was impossible to calculate the commercial results, as the receipts were not known, nor the price paid for the land and for compensations.

There was no necessity for the existence of such a state of things, either at Croydon, or elsewhere. If the Boards of Health would carefully examine the nature of the material with which they had to deal, they would soon come to the conclusion, that there was, in general, no pecuniary advantage to be derived from it as manure; and that their duty should be simply to deodorise it, in order to prevent its becoming a nuisance. The process of straining, adopted at Croydon, effected the separation from the sewage, of the bulky portions of the decomposing animal fibrine and albumen, and these gave forth that insufferable odour which prevailed at the works, when the deposited matter was thrown out of the tanks. The Birmingham sewage works had, for a similar reason, become a disgusting nuisance to the whole neighbourhood. If that matter, however, was deodorised, by mixing with it a sufficient quantity of lime, it would make a good dry manure for the land. The first operation, therefore, should be to precipitate from the sewage water, all that was possible, by the application of quicklime, or of some other equally effective agent. By this means the water would be rendered perfectly clear, although not more than one-fourth of the organic matter would be precipitated; but this was the portion which would, otherwise, most speedily run into offensive decomposition. But the lime process was insufficient for the treatment of the sewage, when used for irrigation purposes in the vicinity of towns, or residences; it was necessary to use an antiseptic, than which none was superior to McDougal's fluid; the water would then be rendered innocuous, and it might afterwards be allowed to pass into the river, unless the river happened to be valuable as a fishery, or was used for other purposes inconsistent with the employment of McDougal's fluid. Decomposition was produced, not only by offensive putrefaction, but also by eremacausis which did not create an unwholsome smell, and which was effected by the oxygen of the air and the water. The organic matter was largely decomposed by merely flowing down a sewer, if there was abundance of water through which it could become diffused; and the consequence was, that the sewage became valueless, having lost its fertilising properties. If the principles he had enunciated were recognised, the idea of making the sewage matter of towns commercially useful, would be altogether abandoned, and means would be at once taken, to prevent the further pollution of the rivers.

WATER RIGHTS.

Mr. HAWKSLEY said, that he was not inclined to limit the right of a person to pump from a spring upon his land, as much water as he pleased. He regarded underground water in the same light as he looked upon game; that it might be taken by those upon whose property it was found. It was impossible to say positively, in the majority of cases, that the water drawn by one person came from the land of another, and still less, that it was his property; in fact, the course of underground water could not, in general, be pursued to its origin. This view of the case might, possibly, be attended with hardship, in individual instances; a person might have established a business dependent on the use of the water, but even then he did not think, that if any other person sunk a well at a distance, and pumped his water from the same ground, there would be any legal cause of complaint. Having been concerned in conflicting cases of underground water, he believed it was impossible to adopt any other system of adjudicating upon such rights, than that which had been generally laid down by the Judges. As to water flowing over the surface, there had been some decisions, lately, of an exceptional character; such, for instance, that no one could begin to have a property in water until it ran in a continuously flowing stream. That principle had been laid down, in the case of Broadbent *v.* Ramsbottom.[1] Now in rocky, or clayey ground, although a stream of great importance might flow during several months of the year, and be valuable for manufacturing purposes, yet it might cease to flow during three months out of the twelve. The Bourne, which was the source of the River Wandle, would come under the same category, since it only flowed down a defined channel, once in a certain number of years. During that time, it was, of course, of considerable value to those through whose land it flowed; but it would result from that decision, that there could be no property in the water of the Bourne, till it reached the Wandle.

Mr. J. **Horatio Lloyd** observed, that, wherever there was a defined stream in a defined course, although intermitted, there might be a property.

Mr. J. **Hawkshaw**, V.P., deprecated the introduction of the law of water rights into the discussion, which should be confined to matters within the sphere of Civil Engineering. A large social question had been raised, and legal decisions impugned, with which the Institution was incompetent to deal, and which it ought not to entertain, to the neglect of the professional points of the subject.

Mr. **John Evans** thought, that taking into account the well-known natural laws which regulated the flow of water through chalk districts, there had been a grievous mistake in the legislation upon this subject, which was based upon the assumption, that the course of underground water was entirely unknown. The laws relating to the uses and rights of ownership of water flowing above ground, were clear and well defined. There was a certain limited use and ownership allowed, and any undue use, or abstraction of such water, could immediately be checked. Yet by a recent decision of the House of Lords, it was held, that provided the water flowing into a river by an underground course had not become visible, or reached the surface, it might be abstracted with impunity, even within a few yards of the river; so that it was held, in fact, to constitute an entirely different species of property. It appeared to him, that the property in water, whether upon the surface, or under it, ought to be regulated by the same social laws, in all cases where the same natural laws applied equally to both. The law ought to operate in the one case as in the other, and the maxim of law, "Sic utere tuo ut alienum non lædas,"—so to use your property as not to injure the rights of another,—should be carried out in both cases.

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[1] *Vide* "The Weekly Reporter," February 9, 1856. In the Court of Exchequer, January 12, 1856.

Mr. W. Drummond said, that as he had assisted in conducting the somewhat celebrated case of Chasemore *v.* Richards,[1] or Chasemore *v.* The Croydon Local Board of Health, which had been taken from the Court of Exchequer to the House of Lords, and had now decided the vexed question of rights in underground water, it might be interesting to the Meeting to hear how the law now stood, according to this final decision. While the Croydon Board were spending £55,000 in their waterworks and drains, the law, (according to the reported cases,) was, that though an owner of land might not divert, or pump away water visibly running above ground, if by so doing, he worked an injury to a millowner, or other riparian proprietor,—yet he might pump and use, or divert, any amount of underground water, although by so doing, he might injure other proprietors. The course and direction of underground waters were considered too uncertain and too little known, to be the foundation of any rights in them. But the Croydon Board had no sooner dug their well, completed their works, made this large outlay, laid on the water to all the houses, and destroyed the old wells, than the case of Dickinson *v.* The Grand Junction Canal Company was decided, and appeared to reverse the law. The Canal Company had sunk a shaft in a chalk hill, and had pumped water to their upper level. Mr. Dickinson proved, that their pumping diminished his mill stream, and he obtained a decision in his favour. On this decision being known, Mr. Chasemore, the occupier of the first mill on the Wandle, ascertained by gauges, that the pumping of the Croydon Board from their deep chalk well, had lessened his mill power, and he brought an action against the Board for damages. If the Croydon Board had not reversed the decision in Dickinson *v.* The Grand Junction Canal Company, the grass would have grown in the streets of Croydon. The inhabitants would never have re-opened their old impure wells, and they could not have compensated Mr. Chasemore, as all the other mill-owners lower down the river, could have claimed the same amount of compensation. They, therefore, resisted the action, and fortunately, but justly, they succeeded. An appeal was made from the Court of Exchequer to the Exchequer Chamber, but the latter confirmed the decision in favour of the Board. Finally, Mr. Chasemore appealed to the House of Lords. On the hearing, Lord Brougham said, that considering its bearing on mining and on a variety of engineering works, on private wells, on ponds, and on waters, it was one of the most important cases that had ever been brought before that tribunal. The Lords first took the opinion of the Judges, and afterwards delivered their decision, which was in favour of the Croydon Board. He believed no case had ever been studied with more thorough research, or had been more satisfactorily argued on both sides. The result of this decision of the House of Lords was, that water percolating under ground, like the air above ground, was unpropertied, and was not the subject of any prescriptive rights. Any owner of land might take as much as he liked from beneath his own land, and if he dried, or injured his neighbour's well, or mill stream, or pond, the neighbour had no remedy against him. He must sink a deeper well, or seek for water in other directions. Mr. Drummond differed completely from the opinion, that the decision was incorrect, or unjust, and that there were any hopes of a reversal. He was satisfied, and he believed the bar was satisfied, that this was a just decision, and that the question might now be considered, as irrevocably settled.

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[1] *Vide* "The Weekly Reporter," August 27, 1859. Vol. vii., p. 685. In the House of Lords, February 12, June 11, July 19 and 27, 1859. 7 House of Lords' Cases. Page 349.

Mr. Bailey Denton observed, that the decision had already been reversed by Vice-Chancellor Stuart, in the case of Ennor *v.* Barwell.[1] The Vice-Chancellor, in delivering judgment, particularly referred to the cases of Chasemore *v.* Richards, and Broadbent *v.* Ramsbottom. The decisions on these cases were disregarded. It was held, that underground water was the property of the person whose land it would reach, by percolation and gravitation from a higher to a lower level. That decision, however, had not yet been confirmed by a higher court.

Mr. Hawksley did not consider, that the recent decision of Vice-Chancellor Stuart had reversed the previous judgments, with regard to underground water rights. He had carefully read through the whole case, and in his opinion, it was confirmatory of the decisions of the Common Law and Equity Judges and of the House of Lords.

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[1] *Vide* "The Law Times Reports," October 20 and 27, 1860. In Vice-Chancellor Stuart's Court, June and July, 1860.

Mr. J. Horatio Lloyd dissented from the opinion, that legal questions, especially those concerning water rights, were entirely foreign to engineering pursuits. Looking to the varied character of the duties which he might be called upon to discharge, and of the questions with which he had to deal, the Engineer should possess some knowledge, not only of chemistry, of geology, and of mineralogy, but also of the law which related to particular points of practice. Some of the questions relating to water rights had not, at present, been very satisfactorily determined. The law, indeed, might be considered, generally, as in a state of transition. The Judges were obliged to decide according to the peculiar circumstances of each case, as they often had no written law to guide them. In the course of the discussion, certain principles had been laid down, from which he dissented. He would, therefore, state in general terms, what he conceived to be the law with regard to water rights, so far as it might, or could affect the Engineer. The law, as it stood at present, dealt differently with the two questions of water above ground and water under ground. Where water was flowing in a defined channel upon the surface, its action and effect might be seen and appreciated, and the proprietor of the land through which it passed, had a right to use it for all reasonable purposes incident to his occupation of the land. That right, however, had this limit; the maxim of law must be observed, that a man must so use his own property as not to injure his neighbour's. Then came the question, what constituted such an abuse as would contravene this maxim? First, nothing must be done wilfully, wantonly, or negligently, the effect of which would be to take away, or lessen the benefit to which proprietors, or occupiers below, were entitled. Thus, in the case of millowners requiring water power, no person at a higher point of the stream, had a right to do any act which would either diminish the water power, or send forward the water in a different state from that in which it was ordinarily received; he had no right to divert, or to foul the water. Nevertheless, by long, 'users,' a right might be acquired, to do both, or either, as against the riparian proprietors below; the law presuming, from long enjoyment, or acquiescence, a grant, from all parties interested, of the privilege by the use of which they were affected. Twenty years' uninterrupted enjoyment was sufficient to confer this right but it must be strictly exercised according to the previous use; any excess would, of course, give a ground of action. These general points were easy and familiar to all lawyers; but the question, relating to underground water was more difficult. There were two ways in which water would find its way underground, from one spot to another; by percolation, or filtration, or by streams which, though not seen, might be traced in their effects. In the former of these two cases, the courts had decided, that there was no right in such water, of which legal cognisance could be taken; and consequently, that although by digging a well in one's own ground, the neighbour's well was drained, there was no ground of action in that case. This frequently occurred, for example, with the wells of the large London breweries; but the Courts had decided, that they could not interfere, not because the abstraction of the water from another was not an injury and, ethically, a wrong, but because there existed no means of ascertaining and tracing out the fact, with anything like legal certainty. The water, in such cases, could not be identified. It could not be asserted, that the very water which, before the operation complained of, was in a particular well, was the same water which had found its way into another well, at some distance. Accordingly, the Courts declined to apply to a matter so obscure, the same rules which were applicable to visible and defined surface streams. Then came the further question now under consideration, and which would, probably, before long come formally, before the Courts. When water passed underground, as in the former case, not by percolation merely, but in a current traceable by physical means, so that the water flowing in such current could be itself identified, the question arose, whether in the absence of a prescriptive right, that water could be abstracted, or be contaminated, so as to deprive another of its beneficial use which he had previously enjoyed. His own opinion was, that it would be, eventually, determined, that the interference with such water, either by abstraction, or by fouling, was a wrong for which an action might be maintained.

Mr. Bidder,—President,—observed, that he was personally interested in the condition of the Wandle, being the owner of a portion of that river, and unfortunately, whether from the operations of the Board of Health of Croydon, or from some other cause, he was suffering, in one part of his property, to the extent of £100 per annum, which would, probably, be increased to £200, or £300 per annum, if the nuisance was not abated. It had been urged, that local interests should not be allowed to stand in the way of the improvements necessary for the health of towns. Now he thought that was a gratuitous exhibition of humanity and benevolence, but too common in the present day. It was the main object of the Legislature and of the Courts of Law, to render justice to all parties, but they were, occasionally, misled by enterprising witnesses and ingenious advocates, to give decisions at variance with those principles of right, which it was their object to maintain. It was manifestly unjust, because a town had arisen upon the banks of a river, that the private property in its neighbourhood should be sacrificed, by the transformation of the river into a foul ditch, and it was upon this ground that, at the opening of the discussion, he had given his opinion, that the question could not be satisfactorily discussed, without reference to the general principles of law which applied to these cases. Towns were arising in the vicinity of the banks of the Thames and other rivers, with populations rapidly increasing, and the streams were becoming polluted to a very serious extent; he thought, therefore, that the time had arrived, when the Legislature must direct their attention towards devising means for preserving the salubrity of the rivers, which formed so striking and beautiful a feature in the landscape scenery of England.

The River Wandle was an especial object of interest, as from its proximity to London, it had been suggested as one of the sources of water supply for the Metropolis. But it had been shown, that its flow was subject to great fluctuations. The minimum current that had been recorded, about 10,000,000 gallons per day, would only be sufficient for the supply of three hundred thousand inhabitants, or about one-tenth of the population of London. The variable amount of water in the Wandle, was not commensurate with the rainfall. The proportion of the rainfall flowing off by means of rivers, could not be determined by any system of averages, but only by a series of recorded observations, during many years, upon a particular soil in a particular district, and even then, these observations would not apply to any other case. Upon certain lands on the banks of the Wandle, he had noticed, that, between January, 1858, and September, 1859, although 23 inches of rain had fallen (at some periods, as much as 1 inch in two, or three hours,) none flowed off the surface of the land. Between September and November, 1859, there were 10 inches of rainfall, and not till then, did the water begin to pass through the sub-drains into the river. A rainfall of about 30 inches had thus been evaporated, or been absorbed by vegetation, upon drained land. That fact proved to his satisfaction, that one of the effects of sub-drainage was, by increasing the fertility of the land, to create a greater demand for moisture. This remark might not be applicable to other districts, because the supply to the rivers depended upon the varying nature of the soil, and upon the seasons. During a portion of the time over which his observations extended, it was a dry season, with plenty of sun, and there was a luxuriant vegetation, whereas last summer, one-half the quantity of rain would, probably, have been sufficient to supply a larger amount to the springs and rivers in the district to which he had alluded. He made these remarks, with the view of counteracting the tendency to draw averages, and to form diagrams applicable to the whole of the country.

He would premise his observations relative to land drainage, by remarking, that the opinions of Mr. Bailey Denton, (M. Inst.

C.E.,) carried considerable authority, on account of his great experience, and of his laborious investigation of the subject, upon which it was to be hoped he would present a Paper to the Institution. But the President was compelled to differ from him, on the question of deep drainage, as he was convinced, that if the moisture was kept 2 feet 6 inches below the crops, the most suitable depth would be found for all the purposes of vegetation. The late Mr. Tycho Wing had ascertained, by personal investigation, and by carefully-conducted experiments, extending over large areas and continued during many years, that vegetation suffered in dry seasons, when the permanent streams of water were below that depth, and also in wet seasons, if that depth was much exceeded. There were, no doubt, in certain cases, local considerations arising from the nature of the soil and from the existence of springs, which might render it desirable to drain to a greater depth, but he maintained, that it was not a sound principle to adopt a universal depth of 4 feet. The great expense of such a system of drainage was not in the cost of the pipes, but in the labour of excavating and filling up the trenches. For his own part, he would prefer constructing two miles of shallow drains, to one mile of deep drains, and he believed, that by so doing, he would not only save expense, but would also bring the land into better condition for vegetation.

The last point to which he would allude, was the question of outfall. There were many cases where a large area of land was deteriorated, in consequence of the outfall not being 12 inches, or 18 inches lower. This could, no doubt, be remedied, by interfering with private rights, which should always be made subservient to the general good; but at the same time, the law justly provided, that ample compensation should be given. In the north of England, a custom prevailed with regard to collieries, called 'way-leave,' and the same principle was applied to railway companies, who were compelled to compensate the owners, as well as the occupiers of property through which they were desirous of passing. If a man sought to use his neighbour's land for his own benefit, it was only just, that the advantages which might accrue to his estate, or to his mill, should be divided with the landowners through whom alone he could secure them. The authority of the Duke of Northumberland had been cited in favour of deep drainage, but however high might be the social position which he occupied, it gave no weight to his opinion upon practical questions of this nature.

In conclusion, he observed, that he had invited discussion upon many points not directly bearing upon the Paper; but he thought the Meeting would approve of the scope which he had given to it, on account of the importance of all the questions which it had embraced:—land drainage, the value of town sewage, the management of sewers, the principles which should guide the future conduct of local boards of health, and the legislative measures necessary for preventing the further pollution of the rivers of England.

January 29, and February 5 and 12, 1861.
GEORGE PARKER BIDDER, President,
in the Chair.

The discussion upon the Paper, No. 1,023, "On the River Wandle, its Springs, Tributaries, and Pollution," by Mr. Frederick Braithwaite, was continued throughout these evenings, to the exclusion of any other subject.

At the Meeting of February 5, the following Candidates were balloted for and duly elected:—JAMES NICHOLAS DOUGLASS, WILLIAM GILBERT GINTY, MICHAEL LANE, and PHILIP JOHN MESSENT, as Members; FREDERICK DALE BANISTER, ALEXANDER BREMNER, TELFORD FIELD, RICHARD HALL, JOHN KELK, WILLIAM WEBB MOORE, HUGH ADAMS SILVER, EDWARD HENRY THORMAN, and ALBERT AUGUSTUS WYNNE, as Associates.

At the Meeting of February 12, before proceeding with the discussion, the President directed attention to the Donations to the Library, which had been received during the present Session; particularly noticing the handsome edition of the very detailed account of the "Construction of the Great Victoria Bridge, in Canada," from the Author, Mr. James Hodges; the "Report on the Ganges Canal Works," in three volumes, with folio atlas of plates, from the Council of India, through the Author, Colonel Sir Proby Cautley, K.C.B.; a useful German periodical, entitled "Zeitschrift für Bauwesen," from the commencement in 1851, from Mr. W. W. Collins, (M. Inst. C.E.,) who had also presented a copy of Messrs. Tolhausen and Gardissal's "Technological Dictionary in the English, French, and German languages;" and the Official Descriptive and Illustrated Catalogue," with "Reports by the Juries," of the Exhibition of 1851, in six volumes, imperial 4to, from Mr. Andrew Cuthell, (Assoc. Inst. C. E.) The President, in proposing that the cordial thanks of the Meeting be given to the several donors, expressed the hope, that these excellent examples would not be lost upon the many new Members and Associates who had recently joined the Institution, and that it would be the constant aim of the Members of all classes, to maintain the Library in the highest possible efficiency.

February 19, 1861.

GEORGE PARKER BIDDER, President,
in the Chair.

No. 1,032.—"On the Results of Trials of Varieties of Iron Permanent Way."[1] By FRANCIS FOX, M. Inst. C.E.

IN offering to the Institution the following account of trials made under his direction, of some varieties of Iron Permanent Way, the object of the Author is not to put himself forward as an advocate for the superiority of either of the systems tried, over other meritorious inventions, nor even to maintain the superiority of iron over timber for the permanent way, under any and all circumstances; but simply to state the results of actual trials, and the conclusions to which they have led, due allowance being made for their comparatively limited duration. It must, therefore, not be deemed an omission, if no allusion is made to other systems of iron way, which have been introduced during the last few years.

The cost of the renewal of the permanent way of railways, consequent on its comparatively rapid destruction and decay, has become a question of great importance to railway companies, and therefore, to the Engineers in charge of the lines. In the early history of railways, the inevitable cost of replacing, at no very distant period, the materials of the permanent way, if not altogether overlooked, was not sufficiently considered. In the absence of experience, and prior to the enormous increase of traffic, and to the introduction of a heavier class of engines and carriages, too long a duration was generally assigned to the rails and sleepers. It was, perhaps, natural, that on the opening for traffic of a new line of railway, constructed throughout of sound materials, it should not have been imagined, that in every fifteen, or twenty years, the entire permament way would require to be renewed; and that, therefore, its entire first cost, divided by fifteen, or twenty, (but less the value of the old materials,) would represent the constant annual cost of renewal, to which must be added the not unimportant item of labour. For several years past, however, this matter has forced itself on the attention of railway companies, and where the outlay has been very large, and has all been charged to revenue account, a reduction has, in some cases, been made in the dividend, and in others, it has been averted by the creation of suspense liabilities, with the object of spreading the cost over future years. In a very few instances a depreciation, or contingency fund has been formed on the opening of the railway; but the policy of this arrangement has been contested, and its discussion is not within the scope of this Paper.

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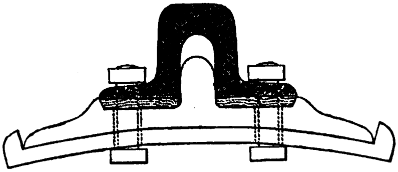
[1] The discussion upon this Paper occupied portions of two evenings, but an abstract of the whole is given consecutively.

Since the cost of replacing the permanent way is unavoidably great, in whatsoever manner it may be effected, it is, evidently, of the greatest importance to reduce it to a minimum. With this view, iron has, of late years, been introduced as a support for the rail, and from its superior durability, it appears likely to be extensively used. The longitudinal timber, or 'Brunel' way, when recently and well laid, appears to possess almost all the requisites of a good permanent way. Its continuity renders it safe, by furnishing a direct support to the rail at every portion of its length, thereby permitting the use of a weaker section of rail. Its bulk gives it a firm position in the ballast, and even admits of a deficiency of that material, with less danger to stability, than with some other kinds of way. It is very strong transversely, without being rigid, and the transoms hold the timbers well together, and maintain a correct gauge. It is also smooth to travel over, from its affording a continuous cushion of timber under the rail. Without entering into the question of the relative merits of the longitudinal and cross-sleeper systems, or of the bridge, double-headed, and foot rails, it may be safely affirmed, that the longitudinal-timber way when recently laid, is an excellent system of permanent way. But the case is widely different when the timber way has been laid for fifteen, or twenty years. If not so decayed as to require removal, the timbers become split, and otherwise mechanically injured, so as to be unfit to remain. The transom ends decay at the housings, making the maintenance of a correct gauge a matter of difficulty, and they must either be renewed, or the doubtful expedient of wedging the ends must be resorted to; the screws work loose in the timber, and the joint plates become bent under the pressure, causing a working at the joints, which increases the wear of the rails and impairs the smoothness of the way. Lastly, the timber, when unfit for further use, realises, as firewood, but a small per-centage of its first cost. It is true, that some of the defects just noticed may be lessened, or remedied, by the use of a packing of pine between the rail and the longitudinal sleepers, and by using solid rails with fished joints; but the destruction of the timber by decay, is not diminished by these expedients.

The importance of finding a more durable permanent way than the one just described, forced itself on the attention of the Author, on his taking charge, in December, 1854, of a broad-gauge line of about 120 miles in length, on which the Brunel way had been laid about fourteen years, and on which the renewal of the timbers had already formed a heavy item of expenditure. An inducement to adopt a continuous rolled-iron rail-bearer, in preference to other forms of iron way, existed, from the circumstance of an experimental length of a quarter of a mile of double line, on a system introduced by Mr. J. J. Macdonnell, (M. Inst. C.E.,) having been down for eighteen months, and having, so far, appeared to answer. Fig. 1 represents a section of the Macdonnell way, as laid down in 1853. The weight of the longitudinal rolled-iron bearers is not uniform, but they average 83½ lbs. per lineal yard; their width is 11 inches. They are in lengths of even feet, for greater facility of exchanging the rails when worn out, (20 feet being the most usual length,) and they are united by joint, or saddle plates 30 inches in length and weighing 56½ lbs. each, the edges of the saddle plates turning up, to clip the ends of the bearers. The sides of the bearer have an inclination with regard to the centre part on which the rail bears, the rise in the middle being $\frac{9}{16}$ths of an inch; the object of this curvature is to give greater vertical stiffness to the bearer, and greater lateral stability in the ballast. A rib, or tongue is rolled in the centre of the upper side, for the double purpose of increasing the strength, and of securing the bridge rail in its place, into the hollow of which the tongue approximately fits. The rails originally laid are unusually light, being only 53¾ lbs. per yard. Between the rail and the bearer, a packing of pine ¼ of an inch thick, was originally placed, the grain of the wood being in the direction of the length of the rail. The packing is confined in its position, by projections rolled on the bearer, as shown in the section. The object of the wood packing, is, by preventing the contact of iron with iron, to lessen the rigidity, and the consequent wear of the rails and rolling stock, by forming a partially elastic cushion; and also, to prevent the loosening of the nuts of the bolts. The joints of the bearer are secured by four

Fig. 1.



Section, 1853.

bolts, $\frac{7}{8}$ths of an inch in diameter, passing through the rail flange, bearer, and joint plate, the nuts being uppermost. Each pair of holes is punched in the joint plate at 2 feet from centre to centre, corresponding with the distances of the holes in the rail flange. The holes in the joint-plates are 1 inch square. The joints of the rails are secured by eight bolts, four through each rail. Two of these bolts, at 4 inches from the ends of each rail, screw into a washer, or fang, 6$\frac{3}{8}$ inches long, 1$\frac{1}{2}$ inch wide and $\frac{3}{4}$ths of an inch thick. The two other bolts are at 12 inches from the end of each rail, corresponding with the holes punched in the base. The bolts screwed into the fangs were found to work loose, and they have, generally, been replaced by ordinary bolts. The intermediate bolts are placed opposite each other, at intervals of 2 feet, to admit of a rail being readily turned by unscrewing the nuts; or a new rail with holes punched at the same regular distances, being quickly put in, without opening out the ballast. The holes in the rail flange are punched oblong, 1$\frac{1}{8}$ inch long by $\frac{7}{8}$ths of an inch wide, to allow for expansion and contraction. This system differs from the 'Barlow' way, in having the rail, or wearing surface, separate and easily removable from the bearing surface; but on the other hand, it considerably exceeds the Barlow rail in weight. The transoms, or cross ties are of angle iron, 4 inches by 2$\frac{1}{2}$ inches in section, the vertical position being given indifferently either to the broad, or the narrow web. When the broad web is flat, the ends are turned up to clip the outer edge of the bearers. It is doubtful if this provision is of advantage, except, perhaps, in relieving the transom bolts from undue strain, in the case of sharp curves. The transoms are at average intervals of 12 feet between the two rails, and 24 feet between the two lines. Their ends are bent to the form of the bearer, to which they are bolted underneath, by two bolts at each end, passing through the transom bearer and the rail flange. No 'cant,' or inclination inwards was given to the rail. The bearers were coated with a composition of some kind, before they were laid, but no trace of it is now left; but it does not appear, that any appreciable loss by oxidation has taken place in this, or either of the other sections of iron bearer.

The position selected for the trial of this iron way, was on a straight and level line, at a short distance from a station at which all ordinary trains stop, but which express trains pass at full speed. The ballast on which it is laid is very indifferent, being a loamy gravel which washes a good deal, and which is, therefore, by no means adapted for an iron way. After more than seven years, this length of iron way is in good condition, and bids fair so to continue for many years to come. About one-third part of the rails proved defective, within the first two years, and they were replaced by rails of 60 lbs. per yard. The rails, weighing only 53¾ lbs. per yard, were, evidently, too light. The ballast was, at the same time, drained, by hollowing out between the rails, and inserting occasional drain trunks, 14 inches square, of creosoted timber, leading to the side drains. The thin pine packing laid longitudinally, which was much injured by the compression, especially at the rail joints, was replaced by thicker packing, laid with the grain transversely to the direction of the rail. This has stood exceedingly well.

The bearers and joint plates, transoms and rails, were rolled by Messrs. Levick and Co., of Cwm Celyn Ironworks, at £7 per ton delivered, and the cost per mile of this way, exclusive of the cost of matching and laying, is estimated as follows:—

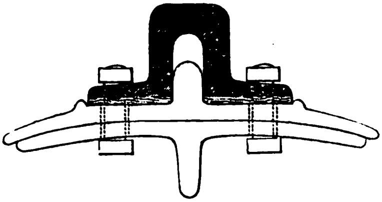
Cost of Section of 1853.

			£.	s.	d.
Rails . .	84¼	tons, at £7 per ton . . .	589	15	0
Bearers . .	131¼	,, ,, ,, . . .	918	15	0
Joint plates,	14¾	,, ,, ,, . . .	103	5	0
Transoms .	17¼	,, ,, ,, . . .	120	15	0
Bolts and washers		. . ,, ,, . . .	145	10	0
Pine packing, 7,040 lineal yards, at 2*d*. per yard .			58	13	4
		Total cost per mile . . .	£1,936	13	4

In order to compare the cost of this permanent way, with that of the longitudinal timber way laid at the same period, it will be necessary to estimate the rails at the same weight and price, in both cases. The cost of one mile of the timber way will thus be £1,850. 15*s*., that of the iron way being as above, £1,936. 13*s*. 4*d*. At the then relatively low price of iron and high price of timber, the difference (£86), is, therefore, in favour of the timber way. Owing to the undue lightness of the rail, both of these calculations must be taken as below the cost of a well-constructed permanent way.

This length of experimental line was obviously too short, to furnish conclusive data as to its merits, in comparison with the timber way, but it was considered by the inspector in charge of it, to cost decidedly less to maintain, than a piece of timber way laid new, at the same time and in continuation of it; and as the experiment appeared, on the whole, to have been successful, it was determined to extend the trial, by laying a double mile of the 'Macdonnell' way at a further distance from the station, so that all the trains should pass over it at full speed. Some modifications of the original arrangement appeared desirable, and they were made with the approval of Mr. Macdonnell. (Fig. 2, p. 264.) As the bearing surface appeared to be too small, the width of the bearer was increased from 11 inches to 12 inches. To lessen the weight, the thickness was reduced from $\frac{11}{16}$ths of an inch to $\frac{9}{16}$ths of an inch, while the curvature was slightly increased, so as not to lessen the strength. The bearer weighs 75 lbs. per lineal yard. The joint plates were reduced to 20 inches in length and 11 inches in width, but they were strengthened by a rib rolled on the under side. The bolt holes were punched at 12 inches from centre to centre of each pair, instead of 2 feet as before. The pine packing (creosoted), was $\frac{9}{16}$ths of an inch thick, and was laid transversely to the length of the rail, the beads for retaining it in place, being much reduced in size. At the rail joints, pieces of hardwood, 18 inches long, laid with the grain lengthwise, were substituted for the pine. The transoms were of T-iron, 3½ inches by 2½ inches, and ⅜ths of an inch thick; and in order to avoid the necessity of bending the transom ends to fit the under side of the bearers, and also to bring the point of connection as near as possible to the crown of the rail, the middle web of the transom was cut away, so as to fit the upper side of the bearer, and the upper web was placed between the rail flange and bearer, the bead being cut away, and a piece of the pine packing omitted. Thus the transom is secured by one bolt only, at each end. It may be observed, that whilst no instance is known of this arrangement of the transoms proving insufficient to maintain the gauge, or of any of the bolts giving way, it seems preferable to extend, where practicable, the ends of the transoms, to nearly the outer edge of the bearers, securing each end by two bolts. The transoms were placed at intervals of 12 feet between the rails, and 24 feet between the adjoining lines. The rails, which weighed 68 lbs. per yard, were of the section now in general use on the line. The fangs, or washers at the rail joints, were omitted. The bolt holes in the bearer were punched as before, but the holes in the rail flange were placed at intervals of 2 feet, on alternate sides, to avoid weakening the rail. No cant inwards was given to the rails, beyond that obtainable by packing the outer edges of the bearers. Before they were laid down, the bearers were heated over a fire and were paid over whilst hot, with tar, but no portion of this coating now remains.

Fig. 2.



Section, 1857.

The contract for the bearers, joint plates and transoms was taken by Messrs. Levick and Co., early in 1856, at the relatively high price of £9. 10*s*. per ton; but owing to the difficulties always attending the manufacture of an article of unusual form, nearly twelve months elapsed before the materials were delivered, and it was not until July, 1857, that the length of nearly a mile of double way was laid. The line at the site selected, had recently been relaid with hard clinker ballast, which forms an excellent bed for an iron, and indeed, for any other kind of permanent way.

The cost of a mile of this arrangement, exclusive of laying, was as follows:—

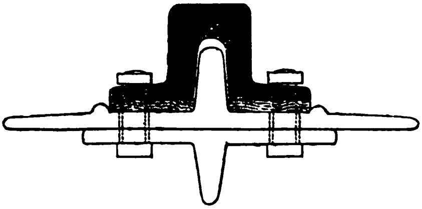
Section of 1857.

			£.	*s.*	*d.*		£.	*s.*	*d.*
Rails . .	106·85	tons, at	9	8	8	per ton .	1,007	11	10
Bearers .	117¾	„	9	10	0	„ .	1,118	14	4
Transoms	10·8	„		„		„ .	102	12	0
Joint plates	9·62	„		„		„ .	91	7	9
Bolts . .	4·13	„	25	0	0	„ .	103	5	0
Packing (pine and hardwood)							88	0	0
		Total cost per mile . . .					£2,511	10	11

It would be unfair to compare this sum with the cost of a mile of the section of 1853, without bearing in mind, that in the arrangement of 1857, the rails were heavier, and that the prices of both rails and bearers, were between 30 and 40 per cent. higher. A mile of timber way, in 1857, laid with the same section of rail, cost about £2,254. The increased cost of the iron way would only be justified, by a reasonable expectation of its greater durability, and diminished cost of maintenance. This expectation appeared to be fully warranted, by the result of about one year's trial of the arrangement just described, together with the equally satisfactory condition of the length laid in 1853; and the Author felt justified in recommending a further trial, on a more extended scale, and on different districts of the railway.

For some time endeavours were made, unsuccessfully, to obtain a reasonable offer from manufacturers, to roll a T-section bearer, which should be stiffer and not heavier than the curved section. The difficulty of rolling and straightening the latter, was alleged to be so great, that it was, ultimately, decided to adopt the flat section shown in Fig. 3 (page 266), which offers no special difficulty of manufacture. As a set-off against the absence of curvature, the bearing surface was increased, by making the bearer 13 inches wide, and the centre rib was also rolled ½ an inch deeper, the weight being thus brought up to 84 lbs. per yard. In the arrangements previously laid, the joints of the rails were, evidently, the weakest part, owing to the loss of the sectional area of the rail, in resisting compression. Rail joint-plates, 14 inches long, of T-section, similar to the bearer joint-plates, were bolted underneath the bearer at every rail joint, and although this addition has succeeded to some extent, the way is still perceptibly weaker at the rail joints than at any other part. The T-section joint-plates of the bearers are 20 inches long, and 8 inches wide. All the holes in the bearers and joint plates are punched, 1¼ inch long by $\frac{15}{16}$ths of an inch wide, to allow for expansion, but more especially, to allow for slight inaccuracies in the punching of the rails and bearers, which, without this provision, caused delay and expense in chipping, when the two were matched together. The end bolts of the rails are as before, but the intermediate bolts are at intervals of 2 feet, and on both sides of the rail. The additional strength thus gained, by holding the upper and the lower sections of the way together as a girder, is considered more than equivalent to the loss of section of the rail flange. The transoms are of angle iron, 3½ inches by 2½ inches, and $\frac{5}{16}$ths of an inch thick, the broader web being vertical. They extend under the bearer to the full width of the rail flange, and they are secured through both, by two bolts at each end. To give an inward cant to the rails, their ends are bent at an angle of 1 in 24. The rails and pine packing are as before, except that the latter is of creosoted pitch pine.

Fig. 3.



Section, 1859.

A contract was entered into with the Rhymney Iron Company, to roll 1,000 tons of this section of bearer with the requisite proportion of joints and transoms, at £9. 12*s.* per ton, and the cost per mile was as follows:—

SECTION OF 1859.

			£.	*s.*	*d.*		£.	*s.*	*d.*
Rails . .	106·85	tons, at	8	13	1	per ton .	924	13	6
Bearers .	132	„	9	12	0	„ .	1,267	4	0
Joint plates	14·59	„	„			„ .	140	1	2
Transoms .	8·74	„	„			„ .	83	18	0
Bolts . .	6	„	17	0	0	„ .	102	0	0
Pine and hardwood packing							53	13	9
Total cost per mile							£2,571	10	5

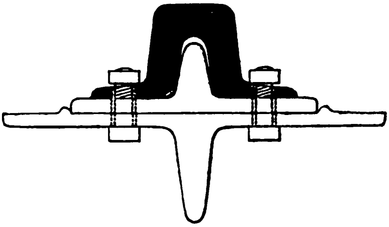
An experiment was made by laying a length of 20 chains of this section of bearer, with the rib inverted in the ballast, instead of being in the position shown in Fig. 3, (page 266). Ten chains of this length were laid with transverse pine-packing 8 inches wide, and the other ten chains without wood packing. The length with packing, has answered very well, but the other, as was anticipated, proved very harsh to travel over; the ballast washed much more, and it was found very difficult to keep the nuts of the bolts tight. At the urgent request of the inspector, packing was inserted in this piece, since which, no fault has been found with it.

In order to test the comparative strength of the different sections of bearer, of rail and bearer combined as laid, and of the rail and bearer joints with, and without joint plates, a series of carefully-conducted experiments were made, with the assistance of Messrs. Stothert and Pitt, of Bath, who have a well-constructed proving machine at their ironworks. The results are shown in the Table, (facing page 274). It may be sufficient briefly to state, that the distance between the points of support was 5 feet. Of the three sections of bearer only, that of 1853 showed the least, and the flat section of 1859 the greatest deflection, under a load of about 5 tons, but in each case the ultimate strength of the bearer did not exceed between 6 tons and 7 tons. Of the three sections of iron way complete, that of 1853 with the 54-lbs. rail was the weakest, and the curved section of 1857 with the 68-lbs. rail, rather the strongest. In two of the cases, some of the bolts gave way, under loads of 11 tons and 16 tons respectively, and the ultimate strength of all the sections was reached, under loads varying from 19 tons to 21 tons. An experiment on the flat bearer, (Fig. 3,) showed, as was expected, the increased stiffness gained by placing the centre rib downwards, thus practically deepening the girder. Other experiments were made to test the strength of the joints both of the rail and the bearer, with and without joint plates; and the absolute necessity for the latter was not only clearly shown, but also the deficiency in strength of those in use. The great vertical strength of the longitudinal timber way is shown in Experiment No. 23, a load of 26½ tons causing a deflection of less than an inch. Its ultimate strength was, however, overcome by a load of 28½ tons, being about 50 per cent. more than the ultimate strength of the iron way.

The results of these experiments tended to strengthen the conviction, that a stronger section of bearer should be adopted, and after about 800 tons of the bearer shown in Fig. 3, had been rolled, the Rhymney Iron Company consented to roll the remainder of the contract, together with an additional 500 tons, of the **T**-section shown in Fig. 4, (page 268,) the additional 500 tons being at the reduced price of £9 per ton. The bearer, in this case, is 12 inches wide, and it is stiffened by a web underneath, 3 inches deep and averaging ¾ths of an inch in thickness. The weight is reduced to 76 lbs. per yard.

The bearer joints are strengthened by angle plates, each 4 inches by 3 inches, and $\frac{3}{8}$ths of an inch thick, the length being 30 inches; eight bolts pass through the upper (and narrower) webs, the bearer and the rail flanges, and two bolts through the vertical webs and the centre web of the bearer, at 18 inches from centre to centre. By this plan a very stiff joint is made. The packing of creosoted pitch pine, placed transversely, is 8 inches wide, and is kept in place by small beads rolled on the bearer. To stiffen the rail joints, which have no plates underneath, and to secure the ends of the rails, an iron plate having a tongue rolled on it, is used, the length being 15 inches; but though this plan supplies, to some extent, the place of the section of rail, the rail joints are still observed to be the weakest portions of the way. To avoid the contact of iron with iron, these joint plates are bedded on a thin wood packing. The transoms are of angle iron, $3\frac{1}{2}$ inches by $2\frac{1}{2}$ inches, and $\frac{5}{16}$ths of an inch thick; and owing to the T-form of the bearer, they can only extend to the middle web. They are, however, bolted through with two bolts at each end, the outer holes being drilled to insure accuracy of gauge, and the cant of the rails being obtained by the insertion of washers between the transom and the bearer. This section of way has been laid too short a time to warrant any decided opinion of it, as compared with the other sections, but as a length of between four, and five single miles of it is under trial, it will soon be seen if it possesses any advantages. It is, as might be expected, perceptibly stiffer to travel over, and the middle web gives it a firmer hold on the ballast than either of the other sections.

Fig. 4.



Section, 1860.

The cost per mile of this iron way is as follows:—

T-Section of 1860.

			£.	s.	d.		£.	s.	d.
Rails . . .	106·85	tons, at	8	2	6	per ton .	868	3	0
Bearers . .	120	,,	9	3	6	,, .	1,101	0	0
Joint plates .	$16\frac{1}{4}$	,,		,,		,, .	149	1	10
Transoms .	$9\frac{2}{3}$	,,		,,		,, .	90	13	10
Bolts and washers	$6\frac{3}{4}$	,,	18	0	0	,, .	121	10	0
Packing							55	0	0
Total cost per mile . . .							£2,385	8	8

This section makes the fourth modification of rolled iron bearer under trial, the entire length being 14¼ single miles. It is now intended to suspend the further extension of iron permanent way, and to carefully watch the working of that already laid, as a guide to the selection of the best form, in the event of future extension.

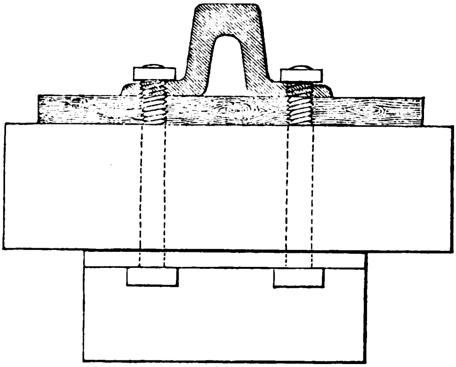
The Macdonnell way having been laid, about three years since, on the Bridport Railway, which is about nine miles in length, and reports having reached the Author of its unsatisfactory working, he went recently over the line to examine the causes of its reported failure. There was no difficulty in ascertaining them, as will appear from the following brief description of the mode of laying it. The bearers are only 60 lbs. per yard, the middle web projects but slightly above the bearer, and the rails are only 53 lbs. per yard; the way is, therefore, very light and weak. There are no joint plates of any kind at the bearer joints, which are, in many cases, between 1 inch and 2 inches wide. The weakness at these points is most apparent, and considering that the line is traversed by heavy broad-gauge engines, the omission of joint plates is most objectionable. The pine packing is only ¼ of an inch thick, laid longitudinally, and there is no hard wood at the rail joints. The packing being compressed out, is of little service either as a cushion for the rail, or as a means of keeping the bolts tight. The latter are continually working loose, and owing to the threads not being cut sufficiently long, it is very difficult to tighten them; and this difficulty is increased by their being round instead of square at the shoulder, requiring the ballast to be opened out and the bolt head to be held by a spanner. The transoms were exceedingly light, being of angle iron 2½ inches by 1½ inch, and they were only of sufficient length to admit of being secured by one bolt at each end. It was found essential to the safe working of the line, to take out every alternate transom, and to replace it by a strong transom of the kind used for the Barlow way. There is nothing to keep the way in its place in the ballast, beyond the slight curvature of the bearer, and it is found necessary to effect this, by driving stakes in the ballast on the curves, and even on the straight line. When it is added, that the gradients are heavy, being 1 in 50 for some length, that the bottom is a yielding clay, and that the chief part of the ballast is of a soft stone, broken originally into very large lumps, it is by no means surprising that, laid as it was, it should prove a partial failure; but it would be manifestly incorrect to condemn this system of iron way, from its having failed through an almost entire disregard of the appliances which the character of the gradients, the curves, the ballast, and the subsoil rendered more than ordinarily necessary.

When, about three years since, the difficulty of obtaining tenders for a T-section bearer was experienced, it occurred to the Author, that a strong and economical iron way could be made, by forming the bearing surface of a rolled flat plate, 12 inches wide and about $\frac{3}{8}$ths of an inch thick, stiffened by an old bridge rail unfit for further use on the line, and of the 60-lbs. section, inverted under the plate, and bolted through to the upper 68-lbs. rail, which beds on pine packing, as usual. A short piece of this way was, accordingly, laid about three years ago, on a line leading from the engine shed at the Bristol terminus, and it has stood perfectly well. The rigidity of this combination, the too great strain on the bolts, and the difficulty of getting a wide, thin, plate rolled at a moderate price, together with the cost and trouble of adapting old rails, led to the trial not being further extended. The introduction of the arrangement is claimed by Mr. W. Bridges Adams.

A trial of the cast-iron sleeper way of Mr. C. De Bergue, remains to be described. This system being well known, no detailed description is thought necessary. The Author felt considerable hesitation in assenting to try this iron way. At first, it appeared like a kind of block road, iron being substituted for the stone blocks. It promised to be very rigid, the bearing surface was small, (only 9 inches per foot forward,) the cast sleepers appeared very liable to break, the nuts of the screw bolts to work loose, (there being no wood packing,) and the wear of the rails to be increased from the same cause. Its chief recommendation was its moderate cost, being about £2,103 per mile, or £300 per mile less than the Macdonnell way of the same period. A trial length, laid on the South Western Line, and well spoken of by the Resident Engineer, was examined, and appeared satisfactory; it was, therefore, arranged to try a length of a single half-mile, which was accordingly laid in May, 1858, in immediate continuation of the Macdonnell way, and on the same kind of clinker ballast. Whilst still preferring a continuous rolled-iron to any cast-iron way, the Author feels bound to state, that none of the anticipated objections have yet been realised to any extent. The De Bergue way is, certainly, more rigid than the timber, or the Macdonnell way, but not a single sleeper has been broken, the nuts of the bolts do not work loose, and the rails wear very well; and with the exception of a little depression at the fished rail-joints, the line keeps as good a 'top' as could be desired, and is as easily maintained as the timber, or the iron way. The cast sleepers are 18 inches by 14 inches, and they weigh 56 lbs. each. The rail is a foot rail 4½ inches high, weighing 62 lbs. per yard, manufactured at Ebbw Vale, the crown being made of hammered iron. The length of the trial, two years and a half, is not yet sufficient to warrant the expression of a decisive opinion on this iron way; but it seems probable, that with some alteration in the arrangement of the sleepers, and the substitution of angle for flat cross ties, a permanent way would be obtained, economical in first cost, and as cheaply, and perhaps more cheaply, maintained, than the timber way, whilst greatly exceeding it in durability, and in the market value of the material, when requiring removal.

There is one other permanent way, which may be termed a continuous stone way, of which the Author must speak with considerable diffidence, both because it appears at first sight, like a return to the stone-block system, so universally abandoned, and because only a very short length of it has just been laid. Although having little, or nothing in common with the De Bergue way just described, the idea suggested itself, that if a cheap, and equally strong, and durable material could be substituted for the cast iron, a very economical way would be the result. A strong, and hard stone, known as the Pennant stone, is found in the neighbourhood of Bristol, which from its strength and moderate cost, appeared well adapted for the purpose. The stone way, (Fig. 5,) consists of blocks of this stone, 24 inches long, 14 inches wide, and 4 inches thick, laid at intervals of only 2 inches to 3 inches, so that the bearing surface is nearly 50 per cent. greater than that of the De Bergue way. For the preliminary trial, a 68-lbs. bridge rail has been used, but a foot rail would, doubtless, be preferable, and with it, the distances between the blocks might be safely increased, if desirable. As an indispensable feature of this proposed stone way, and one which forms its widest difference from the old stone block and chair permanent way, a continuous transverse packing of creosoted pitch pine 1 inch thick, is interposed between the rail and the stone block. The rail is secured to the

Fig. 5.



Continuous Stone Way.

latter by four bolts ⅞ths of an inch in diameter, through each block, the holes being at 5 inches from each end, so as to avoid weakening the block at its centre. As a further precaution against the breaking of the stones, the washers of these bolts consist of pieces of angle iron, placed transversely underneath the blocks. The rail joints are provided with an iron joint-plate having a tongue rolled on it, and are similar to those for the T-section iron way. They are bedded on wood packing. Fished joints would, however, be used with a foot rail. The transoms are of angle iron 2¾ inches by ⅜ths of an inch in section, placed at intervals of 6 feet, but 9 feet, or 10 feet would, probably, be sufficiently near. They are placed alternately underneath the stone block, and immediately under the rail flange, in the openings between the blocks; both rails and blocks are thus kept to accurate gauge. The experimental length is laid on a goods line, over which there is a constant shunting of heavy broad-gauge engines of goods trains. The strength of the way will, therefore, be put to a severe test, before any attempt is made to introduce it on the main line. If the experiment succeeds sufficiently to encourage an extended trial, it is more than probable, that some minor alterations will be found requisite. Taking the rails at the same cost as those for the De Bergue way, but at 6 lbs. per yard heavier, the cost per mile would be as under:—

		£.	*s.*	*d.*		£.	*s.*	*d.*
Rails	107 tons, at	8	10	0	per ton .	909	10	0
Stone blocks . .	No. 4,752, „	0	1	8	each .	396	0	0
Transoms . . .	11⅓ tons, „	9	0	0	per ton .	102	0	0
Rail joint-plates .	5½ „ „		„		„ .	49	10	0
Angle-iron washers	9½ „ „		„		„ .	85	10	0
Bolts	11 „ „	13	0	0	„ .	143	0	0
Pine packing . . .	733 c. feet,	0	2	8	per c. foot	97	14	8
	Total cost per mile . . .					£1,783	4	8

The cost of a mile of the De Bergue way would, at corresponding prices, be £2,103, and that of the timber way, at the present reduced prices for timber, &c. £1,961. Should the stone blocks prove almost imperishable, the difference in first cost is most important; but if from mechanical injury, or gradual decomposition, they should require to be replaced, even after lasting for very many years, it must not be overlooked as an advantage possessed by the iron way, whether cast, or wrought, that its materials when unfit for longer use, will fetch nearly half their original cost.

It now only remains to offer a few remarks on the merits and defects of the continuous rolled-iron permanent way. Its defects, or supposed defects, appear to be:—

1st. The great cost at the present prices, almost precluding its adoption on a railway of limited capital.

2nd. The difficulty of getting it rolled.

3rd. The possible increased wear of the rails.

4th. The greater 'wash' of any but the best ballast, inseparable from all iron ways, resting on, or near the surface.

5th. The difficulty of laying on sharp curves, and of keeping in place when laid.

Its presumed merits are:—

1st. The greater economy in the long run, owing to its greater durability. As an illustration of this, it may be mentioned, that taking the duration of the timber of the Brunel way, at the liberal estimate of twenty years, its first cost at £1,000, and the value of the old timber at £100 per mile, the cost of renewal will be £45 per mile per annum. Taking the cost of the iron bearers at £1,500 per mile, their duration at forty years, and the value as old iron at £660, the cost per annum of renewal will be £21, less than half that of the timber way, without reckoning the considerable item of labour in the replacing of the timbers.

2nd. The saving in maintenance, and the facility for packing, owing to no 'opening out' being required. It is considered by the inspectors in charge of the iron way, that four miles of it can be maintained at the cost of three miles of the timber way. In proof of this, they have consented to a reduction in the number of the men on the districts on which it is laid, equivalent to a saving of more than £600 per annum. Even admitting, that only one half of this amount may prove to be the permanent annual saving, it represents a liberal interest on the additional cost of the iron way, without including the saving in renewal before alluded to.

3rd. The safety of the iron way, especially as contrasted with a timber way which has been long laid.

4th. The facility of exchanging worn rails.

5th. The preservation of a correct gauge.

6th. The lowness of the crown of the rail above the bearing surface.

7th. The saving in the depth of ballast, in the case of a new line.

8th. The equable motion, rendering it probable, that less injury will be sustained by the rolling stock, owing to the absence of the small, but innumerable, blows and jolts which occur on a timber way after being laid some years.

It has been the aim of the Author to state the case fairly, and without undue partiality for the iron, or prejudice against the timber way. A trial of even seven years, though long enough to show, that there is no radical defect in the rolled-bearer system of permanent way, is much too short to prove its superior adaptability, under all circumstances. Moreover, before this kind of permanent way can be extensively adopted, there must be a disposition on the part of the manufacturers, to promote its use by a considerable reduction in the high prices before quoted. If iron for permanent way, (especially rolled iron,) can be supplied at a cost not far exceeding that of timber, and if further experience confirms its entire suitableness for the purpose, there can be little doubt of its largely and advantageously superseding timber, as the rail-bearer of railways.

The Paper is illustrated by a series of diagrams, from which the woodcuts, Figs. 1 to 5 have been compiled.

[Mr. F. Fox

ABLE of EXPE

ese Experiments

s tested was, in al tween the bearings.

Mr. F. FOX said, that since the Paper was written, the stone permanent way had proved a failure. About one-eighth of the stones were cracked across; this would not, necessarily, make the line dangerous, and the cracking might, perhaps, be prevented by using thicker stones, but it would scarcely be prudent to place such a permanent way upon any main line. Having had a little more experience of the permanent way, mentioned in the Paper, as having been recently laid, he was inclined to give it the preference. It remained in good condition, and its superior stiffness gave it an advantage over some of the other systems.

Mr. HAWKSHAW, V.P., observed, that some of these plans appeared to be similar to a continuous iron permanent way, proposed about thirty years ago. He remembered having seen portions of a line laid according to that system, and he did not believe it could be successful. All who were conversant with railway construction knew, that the nature of the ballast was continually varying; sometimes, it was sand; sometimes, burnt clay; and at others, gravel and broken stones. He believed, that the plan of placing flat iron plates on the surface of the ballast, as was proposed in many of the systems, would not answer, on account of the injurious effects arising from frost, and from floods and heavy rains. There was, moreover, a peculiar and an objectionable rigidity in such roads. He thought, that the Barlow rail, the Macdonnell rail, and other similar schemes of permanent way, would prove inferior to the ordinary modes of laying rails. As to their respective cost, it was difficult to make estimates, or comparisons of much practical value, on account of the continual variations in the price of iron. It was, undoubtedly, essential, that the permanent way should be constructed as perfect and as conducive to safety and ease in travelling, as it was possible, whatever might be the cost, within reasonable bounds. Hitherto, on the score of expense, and also to save time, modes of construction, imperfect in some respects, had been adopted. Engineers had been called upon to complete the railways within too short a time; they had, in consequence, been compelled to employ unsuitable ballast, and the permanent way had been sometimes damaged by being used in constructing the earthworks. The ordinary method was that of transverse sleepers of wood with cast-iron chairs, or the plan of longitudinal timbers which had been called the Brunel way, but which was introduced some years before Mr. Brunel applied it. Mr. Hawkshaw was of opinion, that very good roads might be made by either of these methods, and up to the present time, he had seen no other likely to supersede them. He had recently used cast-iron supports, Greaves's pot sleepers, for the rails in India, because he could not obtain wood in sufficient quantities, and at a reasonable price. They answered very well for moderate speeds, and he thought, that if iron was used, Greaves's method was the best. The stone supports shown in Fig. 5, (page 271,) were nearly similar to those tried twenty-five years ago, on the Manchester and Bolton Railway, the whole of which were afterwards removed under his own superintendence. On the portion of road referred to, the rails were laid with perfect accuracy, on large blocks of stone, and there was no doubt, that if they could have been kept in their original positions, the plan would have proved successful; but as mining operations were being carried on under the line, and as the embankments settled, the road soon became very irregular. When Engineers were not restricted as to cost, heavier and stronger sleepers should be employed, good ballast should be procured, and care should be taken, that the rails and chairs were of the best quality, and were properly laid. But the sleepers used at the present time, were of the same dimensions, 10 inches by 5 inches in section, as twenty years ago, when the locomotive engines weighed only 9 tons; and for speeds beyond 40 miles an hour, they were too light. To make a road fit for the description of locomotive and rolling stock now employed, and to travel with the speed now adopted, it would be necessary to expend more at the outset, and then there would be no difficulty in adapting the permanent way, carriages, and rolling stock for speeds of 70 miles an hour; the risk of collision, however, would, necessarily, increase with the velocity. But the stability of the permanent way had not been increased in proportion to the velocity attained, and the load that was, in some instances, carried. If companies reduced the speed of their trains, they might construct and maintain their lines at less cost; but if they persisted in travelling at a high speed, it must involve either heavier expenditure, or jeopardize the safety of the passengers.

Mr. Fowler, V.P., said, that about three years ago, he had examined the Bridport Railway, to which Mr. Macdonnell's system had then been recently applied, and he considered it the worst permanent way he had ever seen. The rails were not sufficiently heavy, the bearings were too slight, and it presented all the other defects of the Barlow longitudinal road, in addition to some peculiarly its own. He thought the Author had fairly stated the progressive steps of improvement which he had attempted, and they were steps of inductive reasoning, such as a careful man would naturally take. Beginning with the Bridport rails, he found they were too light, that the bearings were insufficient, the elasticity was defective, and the hold on the ground was too superficial; he, therefore, slightly increased the bearings. He, next, further increased the bearings, diminished the rigidity, and gained more elasticity. Finally, he still further increased the bearings, taking a greater hold on the ballast; and he thus arrived at a continuous bearing; but experience had proved, that in the cost of maintenance, the plan last adopted presented no advantages over the timber road. Mr. Fowler was satisfied, that the maintenance of an iron road must always be greater than that of a timber road, which was not liable to the disturbances to which iron laid upon the surface of the ground, was continually subject. Not only was the cost of maintenance increased, but the rigidity of the system of permanent way told injuriously upon the rails and also upon the rolling stock. The respective advantages and disadvantages of each system, so far as the Author could judge from his own experience, were fairly stated in the Paper.

The different varieties of permanent way might all be classified under three heads: first, the longitudinal-timber road, with the bridge rail, or some modification of it; secondly, the cross-sleeper road, with double-headed rails and chairs; and thirdly, a description of road which he thought was well adapted for light traffic, which he was now using in Ireland and elsewhere and which had been largely employed on the Continent of Europe, viz., a rail, somewhat similar to the bridge rail, on cross sleepers without chairs. The Engineer must, of course, exercise his own judgment as to which of the systems was best adapted to the circumstances with which he had to deal; but Mr. Fowler thought, that some one, or other of these roads would, in nearly all cases, insure safety in travelling at the speed required in a commercial country.

Mr. WOODHOUSE remarked, that the effect of the rigidity of the permanent way upon the rolling stock, had been particularly exemplified during the late exceptional period of hard weather. Four hundred waggons had been damaged, within a few weeks, and were out of repair at one time, the injury in almost every case having resulted from broken tyres. These fractures were, generally, attributed to the bad quality of the iron, and such, no doubt, was the cause in numerous instances; but he was disposed to think, that the rigidity of the permanent way had helped to produce them. He was unable, at the present moment, to give comparative statements of the loss entailed upon the ordinary narrow-gauge railways laid with continuous rails and cast-iron sleepers, and those laid upon the Brunel principle; but so far as personal comfort in travelling was concerned, and especially during the late severe weather, there was no question as to the superiority of the broad gauge, and the rolling stock of the Great Western Railway had not suffered one-third of the damage which had occurred upon the narrow-gauge lines.

Mr. C. H. GREGORY, V.P., remarked, that the iron road referred to, as Reynolds's, was not of wrought iron, but was a cast-iron continuous bearing, somewhat resembling a trough, and was constructed upon a different principle to the road described in the

Paper. It was but justice to the Author to observe, that h
had not given mere speculative opinions, such as were many of tl
objections which had been raised, but he had stated the resul
of his practical experience, on one of the best-conducted lin
in the kingdom; and while he had alluded to some of the faul
which existed in the earlier forms of iron roads, it appeared th
those faults did not exist in the particular form recommend
by him. Mr. Gregory could bear testimony, so far as he w
able to judge, from riding upon an engine and from watching t
trains as they passed over the line, to the excellent working
the Macdonnell road, as used by the Author, who, moreover, h
opportunities of observing the effects under all the different c
cumstances of weather, &c., and who would, no doubt, state in
reply, how far the objections which had been brought forward we
tenable. The testimony of the enginemen, who were, general
shrewd observers, was, certainly, in its favour, and although he
not consider, that such testimony should, alone, decide the questi
yet he thought, that when there were radical defects in a road
careful engineman would generally remark them. While consid
ing, as he did, that unnecessary discredit had been thrown u
this road, and that it was one of the best iron roads in use, he c
fessed he was not an absolute convert to the system. It was i
portant to have a uniform system of road which could be carr
through the stations with facility, without a break, but the use
most iron roads, in his opinion, materially increased the difficul
at stations and crossings; and he doubted whether the Macd
nell road was applicable to those portions of the perman
way. The De Bergue road was more applicable to stations,
it had not the flexibility of a timber road. That road, as at f
laid down, appeared to him to be too weak, but it had since b
much improved by increasing the weight of the plates. O
of the great merits of that road was, that the sleeper was h
firmly to the rail so as to form a bracket, or extension of
upon which the rail could not work, as it did on many slee
roads. The movement of the rail in its bearing was one of
great difficulties in permanent ways, and so far as he had se
it had been overcome by the De Bergue system; when o
the bolts were screwed up tight, the rail moved very little in
bearing, and he must admit, that the road was not so rigid
might be expected. He thought that many of the evils acc
panying the use of the timber road, might be obviated by dimin
ing the number of fastenings. Mention had been made of a p
in which keys and chairs were dispensed with. He supposed a
sion was made to the Macneill system, which had been largely
ployed in Ireland and elsewhere. From what he had seen of t
system of road, (substituting, however, for the bridge rail, the

dinary single-headed contractors' rail, and using fishes, or brackets at the joints,) he believed it would be found cheap, effective, and simple.

Mr. T. E. Harrison had, only recently, taken up the last portion of the original Hull and Selby Line which had been laid, twenty-four years ago, by Mr. James Walker, (Past-President Inst. C.E.,) and it was similar to that which had been alluded to, as being in use in Ireland; the rails weighed 40 lbs. per yard. He had under his charge, for many years, some roads with longitudinal timbers, and others with cross sleepers; and although he had a strong feeling in favour of the former, he had invariably found, that practical men who had charge of the maintenance, preferred the cross-sleeper road. Much of the damage which had been occasioned by the late severe frost, he conceived to be owing to the insufficient drainage of the roads. He had observed, that where the ballast was of good quality, and the road was laid on cross sleepers, it remained in good condition; but where the ballast was inferior and wet, or upon a clay soil, the road became rigid and distorted. He did not think the injuries depended in any way, upon the different gauges, or the form of the sleepers. With regard to the cost of the two systems, he believed, that the cross-sleeper road could be maintained at the least annual expense. He had carefully inquired into the cost of maintenance of different roads, and he might particularly mention the road between Darlington and York, which had been maintained under the Company's superintendence for a number of years. Over that portion of road, upwards of 1,000,000 tons of mineral and more than 500,000 tons of goods passed annually, and twelve, or fourteen passenger trains daily, each way, several of which were express trains, running at a speed of 50 miles per hour. That road, which was chiefly fish-jointed, had been well maintained for several years, with all the contingent works, at the rate of a man and a half per mile. With inferior ballast, the cost was considerably enhanced. The result of his experience had been to discourage the idea of adopting iron, as a material for sleepers. By the proper application of creosote, the duration of a sleeper might be measured, not by the time in which it would decay, but rather by the period it would be able to resist the loads continually passing over it, and that period could be materially increased by adopting a chair with a broad base. Although the present permanent way was the best that could be obtained under the circumstances, yet he looked forward with confidence to the time, when the profits of the railway companies would permit them to undertake those improvements which were now required. He had found, that the practice of laying the double-headed rail in the chair upon a wood cushion, had not only the effect of preventing the indentation of the under side of the rail, so that when it was turned there was no inequality of surface, but it had also the effect of making the road smoother, and it tended to keep the keys tighter in their places. Mr. Dodds' process for steeling the surface of the rails, had been employed with great success. He had used it for several years, and he believed he was almost the first to test it practically. There had not been a single case of failure in the thirty miles over which it had been used, and rails thus prepared, lasted double the time of ordinary rails; moreover, as they could be turned, their duration might be estimated at about three times that of unprepared rails. The cost of the process, only about fourteen shillings per ton, was very small when the increased durability was considered.

Mr. Dockray could state, from personal experience, that this important subject had been, hitherto, left too much in the hands of Resident Engineers, who were not aware, that the proposed new systems were often only counterparts of others which had been tried and rejected. As an instance, he would cite Reynolds' permanent way, which was used for many years upon the London and Birmingham Railway, and was, to a great extent, similar to, and he believed quite as good, as that introduced by Mr. Macdonnell. It had been stated, that a wooden cushion had lately been introduced between the rail and the chair. But that plan had been also tried on the London and Birmingham Railway, and was not found advantageous, because the rails wore through the cushions, unless the latter were very frequently renewed; it would, therefore, be desirable to know the duration of the cushions under the circumstances alluded to. The double-headed rail system was almost universally adopted throughout England, except upon the Great Western Railway, and a few other lines; but on the Continent and in other parts of the world, where the lines had been constructed after the experience gained in this country, and many of them, by the direct, or indirect agency of English Engineers, the double-headed rail was not so frequently employed. The following Table contained a list of the various descriptions of railway bars exported from England, and their destination:—

Europe.	France.	Formerly, the double-headed rail; now, the broad-bottomed flanch rails, and also Brunel's and Barlow's systems.
„	Russia, Sweden, Denmark, Austria, Prussia, and generally, throughout Germany.	The deep flanch rail.
„	Sardinia and Naples	The single-headed rail, with chair.
„	Italy (in other parts)	The deep flanch rail.
Asia.	India and Australia	The double-headed rail, with chair.
„	Ceylon	The broad-bottomed flanch rail.
Africa.	Egypt	The double-headed rail on Greaves's bearings.
America.	United States	The broad-bottomed flanch rail.
„	Canada.—Great Western.	„ „ „
„	„ Grand Trunk	The bridge rail on cross sleeper.
„	Brazil	The double-headed rail.
„	Chili and Peru	The broad-bottomed flanch rail.

He believed, that any great improvements in the permanent way must be sought for, by avoiding the use of the chair, which constituted the great difficulty with the double-headed rail. That form of rail was, perhaps, the best that could be used with chairs, as it notched well into them on one side, and gave a firm hold to the key on the other. Great importance was attached to the use of the double-headed rail, because it was assumed that it could be reversed, or be turned end for end, thus presenting four surfaces; but in his own experience, he had found little practical advantage to result, for if one of the heads was battered out of shape, the rail would not fit the chairs when it was turned. The sleepers generally used were made of young timber, full of sap, and of such small scantling, that in making the seat for the chair, they were cut nearly half through, so that they presented the least strength where it was most wanted. The chair had always been his greatest difficulty: in whatever way it was fixed, either with keys and pins, or with wedges of iron and wood, the rail could not be kept fast in its place; and there was, necessarily, wear and tear wherever there was motion.

There could be no diminution in the first cost of railways, with the heavy engines now in use, and the high speeds at present attained; economy must, consequently, be sought for in the maintenance. He would, therefore, call the attention of the Meeting to a system of road introduced by Mr. Seaton, which, he thought, possessed certain advantages. It consisted of a longitudinal triangular bearing of timber, laid with its apex upwards, having a saddle rail with a massive head, without any under-cutting, and in this respect, resembling the bridge rail. Its diverging flanches clasped the timber bearing, and excluded water from penetrating under it, and the rail was secured in its seat by screw bolts passing diagonally into the timber. Immediately under the joints of the rail, a thin plate of iron was bedded into the timber by a screw press applied to the head of the rail, and by this means, the joint was made equally solid with the other parts of the line. A cross sleeper placed at intervals under the bearers secured the gauge, and completed the road. This road particularly recommended itself by the simplicity of its construction. It had neither chair, nor key; the head of the rail was not weakened by under-cutting. The rail prevented water from penetrating under it, and thus damaging the timber; the timber bearing had no water table, and the joint plate required no fitting, being laid with precision and rapidity. In 1856, a piece of this road was laid upon the London and North Western line, near Kilburn, and it was still there; but it was at that time defective, on account of the mode of forming the joints. Other pieces had also been laid on the London and North Western Railway, near Bletchley; on the South Western; and also, to the extent of twenty miles, upon the Great Western. The first cost of laying was rather less than that of the double-headed rail system.

Mr. **Strapp** observed, that the half-mile upon the South Western Line having only been laid between two and three years, a sufficient time had not elapsed to form a fair opinion as to its merits, in regard to its ultimate cost. Although the laying was costly, he did not think that instance was to be taken as a criterion, the platelayers never having had any previous experience of that rail.

Mr. W. H. **Barlow** had great experience both in wrought-iron and cast-iron permanent ways; but he could not regard the results with satisfaction. The Barlow rail was, at one time, in great request, and in fact, it had been laid down much more rapidly even than he, as the inventor, desired. Having tried it himself, he soon found that, in consequence of its rigidity, the rail and the ballast were rapidly worn; some of the road had been laid seven years, and was still in use, but other portions had been taken up. The cast-iron road could hardly have been expected to prove a smoother road than one of wrought iron, yet it was so at first, when a portion was laid on the Midland main line; but the uneven wearing of the rail during ten years had rendered it so rigid, that it was now being gradually replaced by a timber road. The addition of an elastic medium between the support and the rail, as described in the Paper, might, perhaps, be successful in lessening the rigidity, and in removing the great defect hitherto attending upon iron roads. It would, however, appear from the statement of the Author, that the plan had not been entirely successful. There were, without doubt, many disadvantages inseparable from the use of timber; but he believed, that on roads which had to sustain the heavy loads and great speeds of the main lines of this country, the employment of timber was unavoidable; and whatever might be its concomitant evils, they must for the present be submitted to. With regard to the alleged difference of wear and tear in the rolling stock during the late frost, according as the sleepers were laid longitudinally and transversely, one of the Superintendents on the Midland Railway had assured him, that there was very little difference in that respect, but that the greatest amount of destruction had occurred on those portions of the line which were badly drained. If the Great Western Railway had been more free from damage than others, he believed it was, in a great measure, owing to the adoption of a more systematic plan of drainage.

Mr. **Vignoles** said, that after having tried a great number of different modes of laying the permanent way of railroads, the result of many years' experience had proved to him, that the best was that which combined a moderate degree of elasticity with the utmost simplicity. It was formerly thought that the road should be as rigid as possible; and not only were the bearings formed of stone blocks laid at intervals, but even a continuous longitudinal range of stone had been used. It was now, however, admitted, that an elastic medium between the ballast and the rail was necessary. But that principle might also be carried too far, several instances of which had fallen under his observation. However he admired some of the systems that had been brought forward, he regarded the road on transverse sleepers of timber, laid with a flat-based rail fished, and without chairs, as the best, the line being, of course, thoroughly drained.

Mr. **Peter Bruff** had very little experience in iron, or longitudinally-supported permanent roads, but the result of his practice led him to give the preference to those laid on cross sleepers; and he believed it would ultimately be found, that the best road would be that in which chairs were dispensed with. No doubt, the present plan of using flat-bottomed rails without chairs, was defective, from the want of an efficient mode of fastening. The dog spikes did not hold well in the soft wood sleepers, especially when the road had been in use for some time. With reference to the fracture of wheels, he had observed, during the late frost, a marked difference as to the rigidity and shock to the wheels of carriages, upon some parts of lines where the road was fished, compared with other parts where it was not fished; and he believed it would be found, that there was less breakage upon the fished, than upon the ordinary chair-supported road. Incidentally to that subject, he would mention, that upon two small lines under his charge, he had recently laid flat-bottomed rails without chairs, of the same section, weighing 62 lbs. per yard; in the one case, with the fished joints upon the sleepers, and in the other case, with the fished joints suspended; he found the difference was greatly in favour of the former plan, although, in both cases, the same number of sleepers was used in a given length.

Mr. **Vignoles** inquired whether the road was as good, or better and easier where the fish was upon the sleeper, than where it was suspended. Competent persons had expressed an opinion, that a properly fished rail was as good in the latter as in the former case. This had an important bearing upon the question of curves, because there would then be no necessity for having the joints exactly opposite each other, which could not be effected without considerable cutting of the rails.

Mr. **W. H. Barlow** observed, that it had been the practice upon the Midland Line, to have the rails for curves rolled in two separate lengths, one half being 1 inch shorter than the other, and to put the shorter lengths inside.

Mr. **Burleigh** considered, that the practical adaptability of iron, as a bearing for rails had been demonstrated, in a variety of forms, by Messrs. Greaves, Adams, De Bergue, and others, but undoubtedly, there were circumstances under which the use of iron would not be admissible; if, for instance, the ballast consisted of unyielding materials, as hard broken stone, or flint, the cast-iron sleepers would be liable to fracture. The pot sleeper was objectionable, on account of the difficulty of packing such ballast, as it had to be inserted and rammed in through a hole in the top. It was also doubtful, whether wrought-iron bearing plates laid on this description of ballast, would form an easy road for travelling, unless an elastic medium were introduced between the rail and the bearers. There were several practical objections to the Macdonnell system. First, there was a want of depth, or vertical strength in the rails and bearers. Secondly, difficulties would arise in cutting the bearers and rails, an operation frequently required on curves, where odd lengths had to be inserted, and at the points and crossings of the stations, but which could not be readily performed by the platelayer. Thirdly, it would be very difficult to bend the bearer laterally in the same degree as the rail, and to match the rails and the bearers, so as to make the bolt holes always correspond, and thus avoid the necessity for drilling fresh holes. In all systems of longitudinal bearings, transoms were objectionable, where they were so wide as to take a bearing upon the ballast. In the Macdonnell system the transoms were formed of angle iron, placed at intervals of about 12 feet, and varying in width and depth, as shown in the different experiments. At these intervals, they practically increased the bearing surface, and when the road was out of order, a series of jerks would take place at such points, in travelling over the line. He had found, that the best transom, or tie, was a flat bar of iron placed vertically, so as to take little, or no bearing upon the ballast, leaving that duty to be entirely performed by the longitudinal sleeper.

Allusion had been made to the process of converting, or hardening rails, introduced by Mr. Dodds, and he could confirm, from experience, that it greatly increased the duration of rails, and of points and crossings. The converting process rendered the rail so hard, that a cold chisel would not penetrate it, and he doubted whether cutting could be easily accomplished by the ordinary means, unless the steeled rail were first tempered. But viewing the process simply as a means of hardening, and of enabling the rail to resist abrasion and wear and tear, he thought it valuable; it was easily effected, and the depth of the steeling could be regulated with great precision. There was no difficulty in carrying out the process, if the oven, or furnace was carefully attended to and was kept perfectly air-tight. Although the use of iron as a rail-bearer was still in its infancy, yet in this land of iron there were fair grounds for hoping, that experience would enable Engineers to introduce such improvements, either by elastic packing, or otherwise, as would render it more generally available, and that iron ways would, ultimately, become the rule rather than the exception. Pot sleepers appeared to have been successfully employed on the Egyptian, and on other railways, though, doubtless, much of the success had depended on the sandy nature of the ballast.

Mr. G. **Berkley** also expressed a favourable opinion of Mr. Dodds' process, as regarded its effects on the duration of those parts of the rail exposed to wear. The rail was, however, somewhat weakened by the process, but not so much as, practically, to affect the sufficiency of its strength. He thought there could be no doubt, that what might be called the surface permanent way of iron, had not yet been found equal to those other descriptions composed of wood and iron, in more general use in this country. The question, therefore, arose, why isolated experiments, which, undoubtedly, had been carefully and accurately recorded, were so much at variance with the results of actual experience, and whether it was more desirable to rely upon the experiments, or the experience. Experiments of this description were often liable to lead to erroneous conclusions, for the materials were, comparatively, new; they were generally fitted with great care, and during the time of the experiments, greater attention was given to the repair of this part of the road, than to others to which special notice was not called.

It had been stated, that to properly adapt the permanent way to the present increased weight and speed of the engines, the original cost should be doubled; but to that proposition he demurred. Twenty years ago, on the London and North Western Railway, the engines had four wheels, and their average weight was about 15 tons; now they were nearly double that weight, but they had six wheels; so that, whilst formerly, there was an average weight of about 7½ tons, there was now, an average weight of about 9 tons, or 10 tons, upon each pair of wheels. The weight upon the driving wheels had also been increased from about 10 tons to 12 tons. With respect to speed, it was wrong to compare the express trains of these days, with the trains twenty years ago, as with express trains, the number of stoppages was much diminished. It was the running speed which told on the permanent way, and that had not been increased more than 25 per cent.; and on the other hand, the permanent way had been strengthened. The rails weighing 65 lbs. per yard had, in many instances, been replaced by those of 84 lbs. per yard, and the chairs of 25 lbs. by those of 45 lbs. There was also one more sleeper to each rail; and the joints of the rail, which constituted the weak point of the old permanent way, had been materially strengthened. Of all the accidents that had happened for some time past, scarcely one could be referred to the weakness of the road. Almost the whole of those which had occurred during the late frost, were attributable to the failure of some portion of the rolling stock, and to the insufficiency of drainage of the lines. He regarded good drainage as the most important point in the construction of a permanent way, yet it was one to which the least attention had been directed. If proper attention was given to secure a sufficient quantity and a suitable quality of ballast, and to obtain good materials in other parts of the permanent way, he thought, that a serviceable road could be made, of most of the forms now generally adopted in this country.

Mr. G. R. STEPHENSON doubted much whether a rail of 66 lbs. per yard, on the London and North Western Railway, was sufficient for an engine weighing 30 to 35 tons, and running with heavy loads, at express speed.

Mr. F. FOX had not expected, in presenting the Paper, that iron roads would meet with the general approval of Engineers. But he must correct the assertion, that these systems of iron ways had only been tried during a short time, for a portion of them had been in use for nearly eight years, which, although, perhaps, not sufficient for forming a decided opinion, was quite enough to enable some estimate, founded on experience, to be given. It had been said, that these plans had been tried and abandoned, many years ago; and Reynolds' trough cast-iron sleeper was particularly instanced, as being almost identical. Now the continuous rolled-iron rail-bearer only resembled that plan in this respect, that iron and wood entered into the composition of both. Mr. Reynolds' sleeper was a rigid continuous trough of a V-shape, (like Mr. Seaton's rail inverted,) bolted at the joints, and absolutely inflexible, although the hollow was filled with a wooden cushion; whereas the rolled iron way was, on the contrary, too flexible. It was not fair to condemn upon mere speculative grounds, the results of experiments which had been honestly made and without prejudice. He had no experience of Greaves' pot sleepers, but they had not been approved of by many Engineers who had tried them; as it had been found that they were troublesome to maintain, and that they sucked up water from the ballast. He did not approve of them, because there was a rigid iron rail resting on sleepers of the same material, placed immediately upon the ballast, and if a cast-iron way was to be used, he gave the decided preference to De Bergue's system. There was also great difference between Hartley's lathe-bed system of stone way and that shown in Fig. 5, (page 271,) in which there was an interval of about an inch of wood, which served as a cushion between the stones and the iron, and gave a certain amount of elasticity. Some of the stones had, however, given way, from not possessing sufficient strength to bear the heavy goods engines. There was a great difference between elasticity and compressibility, and the term 'rigid' had been frequently used in the course of the discussion. It could be shown, from experiments, that between bearings of 5 feet, the double-headed rail deflected less, and was, therefore, more rigid, in respect to flexibility, than the Macdonnell system: but the double-headed rail was not rigid, because it was placed upon timber sleepers, forming a compressible cushion. For the same reason, the rail on the Macdonnell system, being laid on a cushion of wood, the thickness of which it would, probably, be desirable to increase, was not rigid in the sense of want of flexibility. In fact, the forms first tried were too flexible; so much so as to be likely to injure the ballast, and that had led to the adoption of the T-section bearer. The insufficiency of the strength of permanent way had been alluded to; but he thought the longitudinal system, with bearings 14 inches by 7 inches in section, had not shown itself to be deficient in strength, considering the high speeds, and the heavy traffic it had to sustain. He would mention, that, for longitudinal bearings, he was about to try pitch pine, as it was stronger than the timber generally used.

He concurred in the remarks of Mr. Fowler, concerning the Bridport Line, which was, when seen by him, a bad specimen of permanent way; but even the best system which could be imagined, would be pronounced to be bad, if carried out as carelessly, as the Macdonnell road had been on that railway. With regard to the question of maintenance, the Macdonnell system had been used on the Bristol and Exeter Railway, during seven, or eight years, and he believed no greater care had been bestowed on that, than on the other portions of the line; indeed, the greater part was laid at night, which was not the most favourable time for the operation. It was, however, an undoubted fact, that the maintenance cost less, than on the portions of the line laid with timber: one inspector had estimated the proportion as 3 to 4, and another as 4 to 5, but it might be safely stated, at half a man per mile. This saving, equal to about £20 per annum, would be equivalent to the interest, at 4 per cent., upon the additional outlay at the outset. But it was said, that the road which cost £1,500 per mile, and lasted for forty years, at the end of which it would fetch nearly half its original value, was not cheaper, in the long run, than the road which cost £1,000 per mile, and after lasting for twenty years, became worthless. Now, by simple interest, the difference was greatly in favour of the iron road; and by compound interest, the timber road would have the advantage, at first, but the iron way, ultimately. He doubted, however, whether the principle of compound interest was applicable; it would otherwise follow, that those objects which were dear in the first instance, must be the least economical, however long they might last. Without reference, however, to the question of interest, if it could be shown, that the iron way lasted double the time of the ordinary way, and saved the labour and inconvenience of replacing, it must be well worth the additional first cost. If that system had the advantages which were claimed for it, the objection which had been made to its use at stations, was no reason for excluding it from the main line.

Mr. Fox would not enter into the discussion of the relative superiority of longitudinal and cross sleepers, as, although the iron way he had introduced, was longitudinal, it was not a question raised by the Paper, and it was somewhat foreign to the subject.

He would readily admit, that the action of frost upon the iron way, was one of the difficulties of the system, where the ballast was bad, and the line was not well drained. He did not advise the laying down an iron road, under all circumstances, and with every description of ballast. But when laid upon clinker ballast, no difficulty of that kind had been experienced, on the Bristol and Exeter Railway, although on another part of the line, where the ballast consisted of particularly bad gravel, it had given some trouble. He concurred in the necessity of paying more attention to drainage, and in its great importance to the permanent way. He had not found, that creosoting had given that additional durability to timber, which was claimed for it. The creosoted timber in the permanent way under his charge, exhibited a great amount of decay, partly owing, perhaps, to the action of the burnt clay used for ballast. Although, like most Engineers, he now took the greatest care, that the creosoting should be efficiently performed, and not as was often the case formerly, by means of the tar brush, he was not sanguine as to the results. The steeling of the surface of the rails was, too, an important subject, but it was not within the scope of the Paper.

From the experience of the inspector, on a portion of whose district Mr. Seaton's road had been laid, he had not judged favourably of that system. It was liable to work loose at the joints, and the Table of Experiments, (facing page 274,) showed, that the rail was weak; and, although looking at the way in which the timber was cut, to form the continuous bearing, it appeared, at first sight, to be an economical mode, yet it was evident, on reflection, that the edges of the timber would be destroyed in packing, and the practical width of the bearing surface would be considerably reduced. It was, however, due to Mr. Seaton to mention, that the piece of line referred to, was a modification of his system of which he did not approve.

Mr. Fox was sorry, that Mr. W. H. Barlow, (M. Inst. C.E.,) should have arrived at a conclusion unfavourable to the use of iron. The interposition of the continuous elastic cushion constituted an important difference between the Barlow rail and the systems he had tried. In the experiment referred to in the Paper, when he removed the wooden cushion and the rail rested immediately upon the bearer, the bolts worked loose, and the road became so rigid, that he was obliged to replace the cushion. An advantage in this system also was, that the rails were easily replaced, when required; but he had not as yet, observed them to wear out faster upon the iron way, than upon the timber way. The adaptability of the De Bergue, or indeed, of any cast-iron way, on broken stone ballast, was problematical; he did not prefer ballast of this description, except as an excellent draining material. The Macdonnell way was laid upon that ballast on the Bridport Railway, and an opinion had been expressed, that the motion would not be very easy; but in travelling over it he had not noticed, that it was more rigid than other portions of the line. The difficulty of cutting the rails, would not be so great as had been supposed. They were punched at regular distances, viz., at intervals of 2 feet, and they were rolled in lengths of even feet, so that when a new rail was required, not more than 2 feet need, in any case, be cut off; and as the drilling did not cost more than one penny per hole, it amounted to a small sum per mile. He might mention, that before his connection with the railway, a portion of this system was laid upon a curve. The difficulty which had been suggested, had been obviated by making the bearers in short lengths and having a greater number of joints; and many of the bearers being bent in the process of rolling, those were selected for the curves. As to the transom taking a bearing, that was not the case, because the ballast round it was hollowed out; and he preferred the T, or angle-iron transom to a thin bar, because if the latter received a side blow, it would be likely to draw in the gauge.

In bringing this subject before the Institution, it was his desire, not to appear as the advocate of any particular system, but simply to show, that he had tried, during several years different plans of iron way, and that, so far, they were not a failure, but they might be pronounced to have been, to a considerable extent, successful.

Mr. Bidder,—President,—said, that not only with regard to the Paper itself, but also to the concluding remarks of the Author, the Meeting would cordially bear testimony to the candid and practical spirit which he had brought to bear upon the subject, although like all others, he had, no doubt, his predilections. The President, however, participated in the general feeling, that an iron permanent way, at all events, at the present time, was not one which could be safely recommended, and that a sound and safe permanent way must be more effective, than that which was contemplated in the Macdonnell system. He did not believe, having a due regard to economy and efficiency, and to the fact of engines weighing 30 tons, travelling at a speed of from 50 miles to 60 miles per hour, under all the varying circumstances and extremes of weather in this country, that any system of permanent way, which was not laid to a sufficient depth in the ground, could ultimately answer. It was a curious subject for reflection, looking back to the construction of railways, to the great perfection in the bridges, in the embankments, and in the tunnels, that the portion which was to render all these successful, was that which was, perhaps, the least attended to,—the permanent way. In his own experience, he had found the greatest difficulty in obtaining the consent of Boards of Directors to increase the expenditure upon the way, in order to insure its perfect efficiency. He recollected the experiments that were made on the London and North Western Railway, and also those of Mr. Hawkshaw, (V.P. Inst. C.E.,) in attempting to correct the rigid way on the Bolton Railway. He also went over the Great Western Line, where he saw the road being laid on piles, and the rails packed with the utmost nicety, with wood of various degrees of hardness, every rail being laid under supervision, and an engine being sent along the road, to grind them to an even surface. But all roads laid upon embankments, or cuttings, were liable to subsidence, in a varying degree. A permanent way, like all other things in engineering, was a system of compromises. The question was how to sustain a heavy weight travelling with great velocity, and to resist momentum under a great variety of circumstances. There was nothing so certain in mechanical philosophy, as that momentum could only be resisted by momentum; that there was no amount of rigidity, or strength, that could, by tacit absolute resistance, control the smallest amount of force in motion. All permanent ways, therefore, whatever their construction, must, of necessity, be made with a view of permitting a certain amount of motion, in order to contend with momentum. Now the experience of the last twenty-five years had shown, that one system had been adopted almost universally, the double-headed rails, upon chairs, with cross sleepers, a plan which had been materially improved by fishing the joints. The ingenuity of inventors had been exercised, and the bridge rail, and many other descriptions had been introduced; but none had met with universal success. His own conviction was, that the double-headed rail, when of proper materials, with properly-proportioned chairs, and properly fished, was the safest, and the nearest approach to perfection that could be practically attained. There were circumstances, no doubt, of climate and of ballast, which might require some modification of the system; but the Paper only related to the climate and the conditions of traffic in this country. Boards of Directors seldom hesitated to spend large sums, in reducing the gradients on their lines, and he hoped, that this discussion would have the effect of convincing them, that some additional expense must be incurred, in providing better materials for rails, sleepers and chairs, than it had been, hitherto, possible to induce them to sanction.

He would take the opportunity of making some remarks upon the present speed of travelling. He recollected the time, when he thought an engine could scarcely be driven too fast; but now he would never travel again by express trains, if he could possibly avoid it. When travelling at the rate of 50 miles, or 60 miles per hour, if, by any chance, the rails should be out of place, the momentum was sufficient to project the carriages 100 feet, or 120 feet into the air; they were only preserved from accident, by the depth of 1½ inch of the flange upon the wheels. They were, moreover, dependent upon the solidity of the rails, of which there were three hundred and fifty in every mile, with a proportionate number of chairs and sleepers; and they were also dependent upon the perfect construction of the engine, and of every other vehicle composing the train. So far as he was personally concerned, a lower rate of speed would materially conduce to his comfort. But the public demanded a high rate of speed, and moreover, the railways would sometimes compete against each other, without reference to the speed for which their engines were constructed, or the capabilities of the permanent way to support it. He was generally adverse to Government interference, but he thought the railway companies might be fairly restrained from excessive speed, until the strength of the permanent way was increased, and every requisite precaution was taken to insure safety.

February 26, 1861.

GEORGE PARKER BIDDER, President, in the Chair.

The discussion upon the Paper, No. 1,032, "On the Results of Trials of Varieties of Iron Permament Way," by Mr. F. Fox, occupied the whole of the evening, to the exclusion of any other subject.

March 5, 1861.

GEORGE PARKER BIDDER, President,
in the Chair.

The following Candidates were balloted for and duly elected:—**David Hughes Jones**, as a Member; **William Atchison**, **James Samuel Cooke**, **Benjamin Payne Coxon**, **Edward Magdalen Joseph Delaney**, **John Cockburn Francis Lee**, **Robert Charles May**, **Henry Wyndham Sich**, **Joseph Spiers**, **George Taylor**, and **Edward Tyer**, as Associates.

No. 1,033.—"Description of the Pier at Southport, Lancashire."

By Henry Hooper, Assoc. Inst. C.E.

This pier originated with the residents of the town, who had long experienced the want of facility of access to the shore, at low water. From its great length, it has also been found of material assistance, in enabling boats to be launched for the relief of vessels passing to and from the port of Liverpool, which were, not unfrequently, driven on the sandbanks at the mouth of the River Ribble. Of the various applications of wrought and cast iron to permanent structures, in no case, probably, has a more satisfactory result been obtained, by a small outlay, than in the construction of works of a similar character to that now to be described.

Southport is situated thirty-seven miles north-west of Manchester, and twenty miles north of Liverpool, overlooking the Irish Channel, a little to the south of the mouth of the River Ribble. The pier commences at about the centre of, and is at right angles to, the line of promenade facing the sea, and it forms a continuation of Nevill Street. It is constructed on an extensive tract of sands reaching to low water, a distance of nearly a mile, the pier itself being 1,200 yards in length. The superstructure is supported upon a series of piers, (Figs. 1 and 2, page 293,) each formed by three cast-iron columns, 7 inches in external diameter, and 5¾ inches in internal diameter, and each column, or pile, is in three lengths. The lower joint, at the top of the pile, is of the socket form, 8 inches deep, and made good, round the column, with iron cement. The two upper lengths are connected by a flange joint, turned in the lathe, and accurately fitted. The upper lengths of the columns have cast-iron bearing-plates, 1 foot 2 inches by 6½ inches, to receive the ends of the girders, with four holes, each 1 inch in diameter, to receive bolts for securing the girders, the holes being cast oval to allow for expansion, or contraction. The piles proper, or lowest

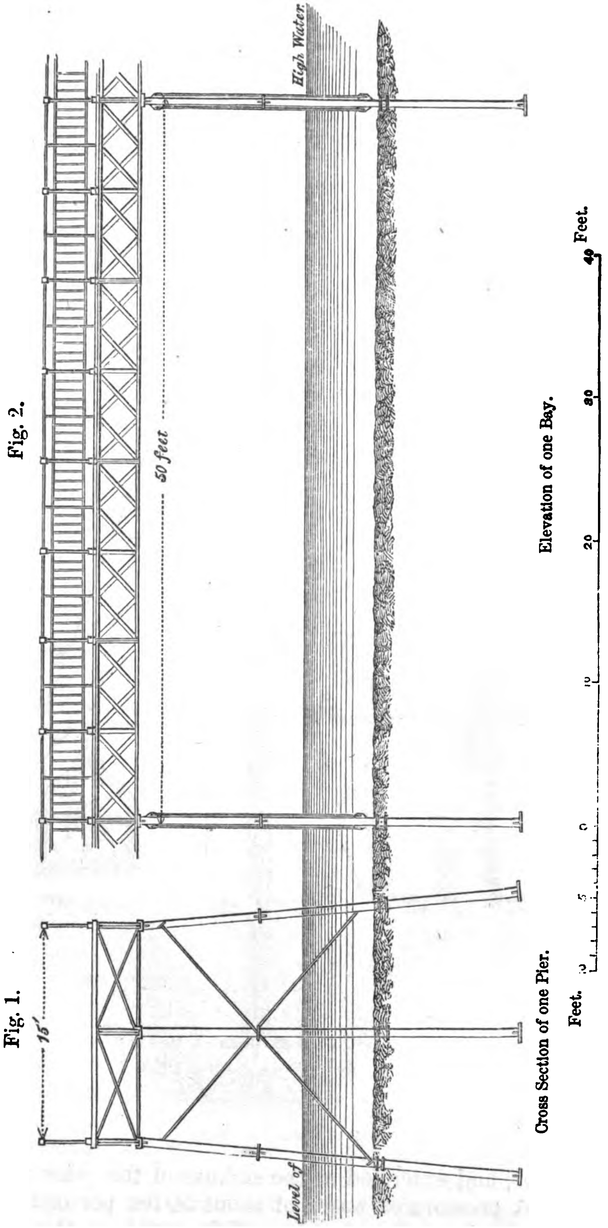


Fig. 1.

Cross Section of one Pier.

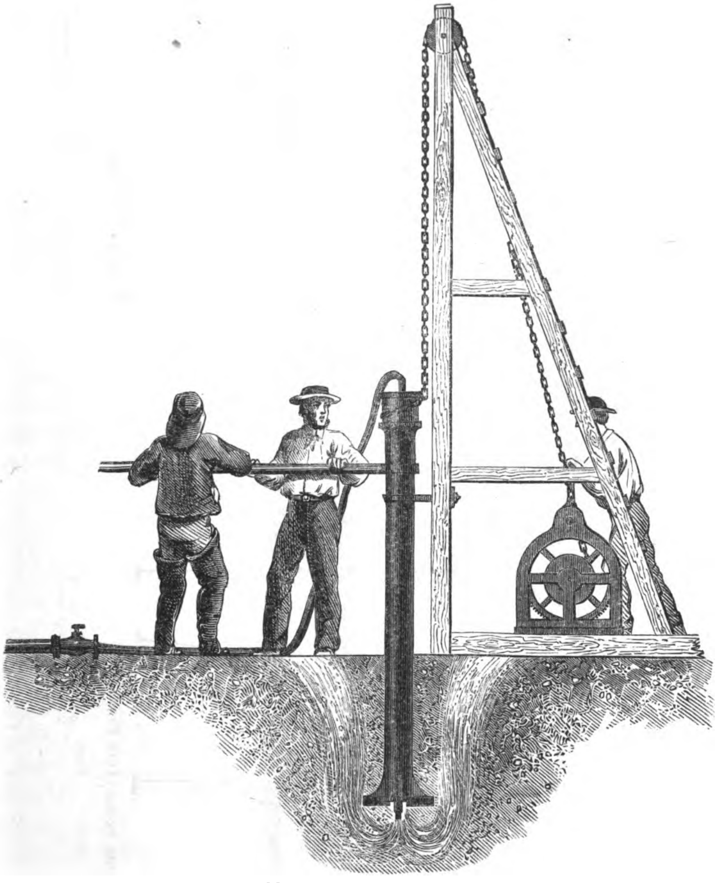
Fig. 2.

Elevation of one Bay.

15′
50 feet
High Water
Level of
Feet.
10
5
0
10
20
30
40
Feet.

lengths of the columns, are cast in lengths of 8 feet and 10 feet, and are sunk into the sand, to the depth of 7 feet and 9 feet respectively. They were provided with circular discs, 1 foot 6 inches in diameter, to form a bearing surface; and, a small hole being left in the centre, a wrought-iron tube, 2 inches in diameter, was passed down the inside of the pile, and forced about 4 inches into the sand, a connection being made, by means of a flexible hose, between the top of the tube and a temporary pipe connected with the water company's mains, and extended as the sinking of the piles proceeded. (Fig. 3.) A pressure of water of about 50 lbs. per inch was thus obtained, and this was found to be sufficient to force the sand from

Fig. 3.



Mode of Sinking the Piles.

under the disc. Each disc was provided, on the lower side, with cutters, which, on an alternating motion being given to the pile, loosened the sand. The piles were gradually lowered, and guided by a small ordinary piling machine. When the pressure of water had been removed about five minutes, the piles settled down to so firm a bearing, that when tested with a load of 12 tons each, no signs of settlement could be perceived. The piers are braced transversely by means of diagonal tie rods, 1¼ inch in diameter, extending from the level of the sands to the under side of the girders, and crossing at and being bolted to the flange joint of the middle column. To break the continuity of the whole structure, and to give stability in the direction of its length, double piers are introduced at three points, thus giving an opportunity of projecting angle-iron brackets, to support seats, clear of the general width of the footway.

The superstructure is 15 feet wide on the footway between the handrails, and it consists of a triple row of longitudinal lattice girders, 50 feet in length and 3 feet in depth, having a bearing, in the clear, of 48 feet 10 inches. The footway is formed of spruce deals, 7 inches by 3 inches in section, laid transversely with spaces of 1 inch for the passage of the wind from the under side, and to prevent the lodgment of water on the upper surface. Each plank is bolted down to the girders by six cup-headed bolts, ⅜ths of an inch in diameter, the two ends beyond the outside girders being finished with a half-round nosing piece, 3 inches deep. The centre girder having to perform double the duty of each of the outside girders, extra strength was given to it, by the addition of top and bottom plates.

The scantling of iron used in the girders was as follows:—

Outside and Inside Girders:—

	Inch.	Inch.	Inch.
The two angle-irons at the top and bottom, each	3½	by 3	by ⅜
The vertical T-irons	4	by 2½	by ⅜
The lattice bars, at the ends . . .	2½	by ½	
Ditto, at the middle . . .	2¼	by ½	

Inside Girders:—

	Inch.	Inch.
The top plate of the middle girder . .	9	by ¼
The bottom ditto	6½	by ⅜

The weight of wrought iron in one bay of the pier, or in a span of 50 feet, is 4 tons, 5 cwt., 4 lbs.

The weight of cast iron in each bay of the pier, is 1 ton, 17 cwt., 3 lbs.

	Cwt.	Qrs.	Lbs.
The weights of the 8-feet piles are . . .	3	2	12
Ditto 10-feet ditto . . .	4	1	7

The second bay from the shore end was tested by a load of 35 tons, equally distributed, when the mean deflection of the three girders, in twenty-four hours, was $1\frac{1}{2}$ inch, and there was a permanent set of half an inch, on the load being removed.

The pitch of the rivets used between the plates and the angle-irons, was 5 inches. Each set of girders was stiffened transversely at each end, and in the middle, by diagonal bracing of angle-iron, with a T-iron purlin at the foot, 4 inches by $2\frac{1}{2}$ inches and $\frac{3}{4}$ths of an inch thick, the purlin alone being used in the two intermediate spaces. The bracing and the purlins were riveted to the girders, by rivets $\frac{5}{8}$ths of an inch in diameter. At the sea end of the pier, there is an oblong platform, 100 feet long and 32 feet wide, at right angles to the line of footway. Two light staircases, 5 feet wide, with open cast-iron treads 11 inches wide, and risers 7 inches deep, supported on wrought-iron raking lattice girders 2 feet 6 inches in depth, securely braced, afford access to the sands at low water, and to boats at other states of the tide.

The hand-rail is formed by cast-iron hollow standards, tapering upwards from 3 inches to $2\frac{1}{2}$ inches in external diameter, the thickness of metal being $\frac{3}{8}$ths of an inch. They are bolted to the girders at intervals of 6 feet 3 inches, from centre to centre, with four bolts, each $\frac{1}{2}$ an inch in diameter. The spaces are filled in with light wrought-iron flakes, consisting of two horizontal bars, $1\frac{1}{8}$th inch by $\frac{5}{16}$ths of an inch in section, and vertical rods of round iron, $\frac{3}{8}$ths of an inch in diameter, placed at intervals of 6 inches. The top rail is formed of T-iron 2 inches by 2 inches by $\frac{1}{4}$th of an inch thick, surmounted by a rounded capping of red deal, 4 inches by $1\frac{1}{2}$ inch in section, screwed on the under side of the top web of the T-iron.

The whole of the cast-iron work in the columns and piles was boiled, for one hour, in a composition of tar and asphalte; and the wrought-iron work and cast-iron standards for the hand-rail were painted with one coat of red lead, when put together, and with two coats of stone colour, when erected. The deals forming the footway were dipped in boiling coal tar, and well sanded on the surface.

The advantages claimed for this mode of construction are:—1st. Great economy in the first cost, especially in sinking the piles. By taking advantage of the pressure of water supplied by the water company, the cost was reduced to four pence halfpenny per foot; whereas in the case of the viaducts over the Rivers

Leven and Kent, in Morecambe Bay,[1] two pontoons were used, each supplied with a donkey engine of 2 H.P. to afford the necessary pressure of water, and the cost amounted to two shillings and sixpence per foot.

2nd. The very small resistance offered by any of its parts to the action of the wind and waves, from which cause not the slightest vibration is felt, while works in the vicinity, of a much heavier character, have been destroyed.

3rd. Similarity of parts, thus reducing the cost of manufacture to a minimum.

4th. The expeditious manner of obtaining a solid foundation ;—an important point in tidal work. All the piles, to the number of two hundred and thirty-seven, were sunk in six weeks, being at the rate of between six and seven in twenty-four hours.

The estimated cost of the pier was £10,400. It has been completed for £9,319, being at the rate of £7. 15*s.* 4*d.* per lineal yard, including a toll house, two registering turnstiles for ingress and egress, one pair of foot gates 9 feet wide, the formation of approaches from the promenade, and the enlarged platform at the sea end.

The design was furnished by Mr. Brunlees, (M. Inst. C.E.,) and the superintendence of the construction was intrusted to the Author, as Resident Engineer ; Messrs. Galloway, of Manchester, were the Contractors.

The Paper is illustrated by a series of diagrams, from which the woodcuts, (Figs. 1 to 3,) have been compiled.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xvii. p. 442.

[Mr. Brunlees

Mr. Brunlees remarked, that as a commercial speculation, the pier had succeeded; the dividend for the last six months having been at the rate of 5 per cent.

Mr. Vignoles would lay down as an axiom for all young Engineers, that success depended not merely upon the character of the constructions, but also upon their commercial results. He highly approved of the plan of sinking the piles, by employing water pressure to disturb the ground below. About fifteen years ago, at the request of Mr. Fauvelle, he prepared a Paper for the British Association,[1] describing the process practically in use by him, in the south of France, whereby the boring wells for Artesian and other purposes, was facilitated by the use of water pressure, which loosened the soil below the boring tool. The principle was not new, but he was glad to hear of its successful application, in the case under consideration.

Mr. Hawkshaw, V.P., had carefully examined, both during its progress and after its completion, a previous work by the same Engineer,—the railway viaduct at Morecambe Bay,—where this system of sinking piles had been extensively employed. The viaduct stood exceedingly well, and appeared to have perfectly retained its form. It was a good and economical mode of construction, and he was gratified to find, that the Southport Pier had been successful, not only in an engineering point of view, but also as a commercial undertaking.

Mr. Bruce inquired, whether in sinking the piles,—stones, or other obstructions had been encountered, and if so, how that difficulty had been met; also, whether there were means of taking up and replacing the piles, as was sometimes necessary, when they were not found to retain their desired shape and position. It occurred to him, that the strength and stability of the platform of the pier would have been increased, if the planking had been laid diagonally, instead of at right angles.

Mr. A. Giles thought, that great credit was due to the Engineer, on acccount of the small cost of the work. It was always desirable, that Engineers should endeavour to make their works as profitable as possible to those by whom they were employed, and they should take the greatest care not to exceed their estimates. Although this pier, in an architectural point of view, appeared, perhaps, too slim, owing to the use of iron piles, yet it was, evidently, well adapted to the circumstances of the case.

Mr. J. Cockburn Curtis had visited the viaduct at Morecambe Bay, while it was in course of construction, and had seen it severely tested by a heavy gale of wind; he was surprised at the absence of all motion in the piles, notwithstanding their unsupported position.

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[1] *Vide* 'Report of the Sixteenth Meeting of the British Association for the Advancement of Science; held at Southampton in September, 1846.' 8vo., London, 1847. Transactions of the Sections, p. 105. Also 'The Athenæum,' Sept. 19, 1846, p. 973.

Mr. Hooper said, in reply, that the soil through which the piles were sunk, consisted entirely of clean sand; no stones, or other obstructions were met with. As evidence of the facility with which the piles were sunk, he might state, that after the pressure from the waterworks was discontinued, half a dozen piles were sunk by means of a common plumbers' force pump. The process of taking up the piles was as simple as that of sinking them; by passing the same water pipe down the side of the pile, the sand was loosened, and the pile could be easily drawn and be replaced in a different position. He admitted, that diagonal planking would have been preferable for the platform; but it would have considerably increased the cost, and due regard had to be paid to economy in this structure. The girders, although tested in place, to the ordinary load only which they would be called upon to sustain, had proved to be of great strength. One of the outside girders was tested at the works, to 27 tons of equally distributed weight; and three of them were capable of supporting a strain of 110 tons, the calculated breaking weight being 120 tons.

In answer to a question by Mr. Murray, Mr. Hooper stated, that the height of the under side of the girders, during an extraordinary high tide, as in 1852, was 4 feet 6 inches above high water; the ordinary height being 11 feet 6 inches. He had never known the water to reach the under side of the girders.

Mr. Bidder,—President,—remarked, that the practical value of the work was not to be measured, either by the shortness of the Paper, or of the discussion. The merits of a work were not always to be estimated in proportion to its commercial success, for the construction of this pier would have been equally satisfactory in an engineering point of view, although a single person had never passed along it. It contrasted favourably with similar constructions at Southend and Whitstable, where the cost had been much greater, and where a large amount was annually expended, to preserve the piers from the ravages of marine insects. The great merit of the Southport Pier consisted in the employment of a material, which was nearly indestructible from this cause, and which offered so little resistance to the sea, that however fragile it might apparently be, its very feebleness constituted, so to say, its greatest protection. It was highly satisfactory, that a pier, 1,200 yards in length, should have been constructed for so moderate an outlay as £9,300.

March 5, 1861.

GEORGE PARKER BIDDER, President,
in the Chair.

No. 997.—"On the Construction of Floating Beacons." By BINDON BLOOD STONEY, B.A., M.R.I.A., Assoc. Inst. C.E.

FLOATING Beacons may be divided into two classes, according to the service for which they are designed:—

1°. Beacon Buoys, which are placed in exposed situations, to mark the position of sunken rocks, sand banks, wrecks, or similar matters dangerous to navigation.

2°. Channel Buoys, which are used for defining the navigable channels of rivers.

It is of essential importance, that all buoys, but more especially those used for sea marks, should be conspicuous in all states of the weather; and for this purpose, they should fulfil the following conditions:—

1°. The superstructure should be erect, well raised above the surrounding water, and presenting a considerable breadth of surface, so as to be conspicuous at a distance. Hence, stability is an essential quality.

2°. The buoy should present a steady object to the view, and be as free as possible, from rolling, and more especially, from abrupt pitching, which not only tends to snap the mooring chain, but also prevents the seaman from deciphering any name, or characteristic mark which may distinguish the buoy, and define its position on the chart.

These qualities of stability and steadiness, in connection with others of great importance, such as simplicity of construction and consequent cheapness of manufacture, are combined in that form of beacon buoy, a description of which the Author now submits to the Institution, and which, from the peculiarity of its construction, has been called the 'Keel Buoy.' Before describing it, however, it may be desirable to notice the various forms of floating beacons hitherto adopted.

BUOYS WHOSE AXIS OF SYMMETRY IS HORIZONTAL, OR OBLIQUE. —The earliest buoys were, probably, barrels, or large casks, and this form is still retained in channel buoys. When the barrel buoy is made of iron, the ends, instead of being square, are slightly rounded, so that the buoy resembles a woolpack, rather than a cask. The barrel buoy is strong, and it is simple in construction, but from its low elevation above the surrounding water, it does not fulfil the most important requirement of a good sea mark.

The Can Buoy has, until within the last few years, been a favourite shape; formerly, it was always constructed of timber staves like a cask, but latterly, of iron plate also. When a can buoy has the name of the sand bank, or rock, which it marks, painted upon it, it is necessary to ballast one side with a small cast-iron keel, so as to insure the name remaining uppermost. The can buoy is not of a conspicuous form, nor does it possess any characteristic good quality, which merits its being longer retained as a beacon; it will, therefore, doubtless, soon be superseded by other forms of greater merit.

BUOYS WHOSE AXIS OF SYMMETRY IS VERTICAL.—The next class of beacon buoys is characterised by a lofty superstructure, of which the cone may be considered the typical form, the body of the buoy being symmetrically disposed around a vertical axis. When the necessity for large floating beacons first arose, it may readily be conceived, that a boat with a cask, or other conspicuous mark fastened to the mast, suggested itself. The Bell Beacon of Liverpool[1] is an example of this class, in an improved form. Wooden spars, springing from the gunwale of the boat, meet together at an apex on the mast, and present the outline of a limpet shell. A globe and bell are attached to the mast. This form of beacon is now being superseded by others specially adapted for the purpose.

Another form of beacon, still sometimes used, consists of a spar, passing through a float, or raft of solid timber, called a deadman. The spar is moored near its lower end, so that it floats vertically, and a globe, or barrel, may be attached to its summit.

Of beacons specially adapted for the purpose, the Nun Buoy first claims attention. In its original form, it presented the appearance of two cones attached by their bases. The Egg-bottomed Buoy is an improved modification of the nun buoy. Its superstructure, which is conical, like a church spire, is formed of sheet iron, riveted to a malleable, or cast-iron bottom of a hemispherical form. This buoy possesses some good qualities. It is simple in construction, and so long as the sea is calm, it is tolerably conspicuous, having a lofty, though narrow superstructure, well raised above the plane of flotation, and held in an upright position, by the combined weight of the metal bottom and the mooring chain. But in a tideway, or under the influence of wind, it inclines over at a considerable angle from the perpendicular, and when the waves rise, it rolls and pitches violently, so as to become an indifferent sea mark.

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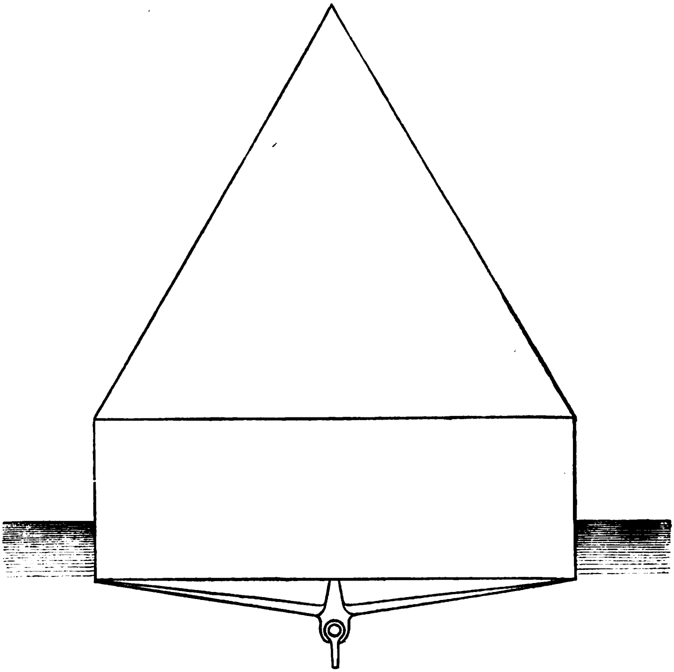
[1] *Vide* "Sailing Directions from Port Lynas to Liverpool, with Tidal Courses and Tide-gauge Table for navigating the Dee and the Mersey," &c. By Commander H. M. Denham. 8vo. Liverpool, 1840. Plate 5, facing page x.

One great defect of the nun, or egg-bottomed buoy is its want of rigidity, arising from the shape of the bottom. This defect is remedied in the buoy represented in Fig. 1, which is made of iron.

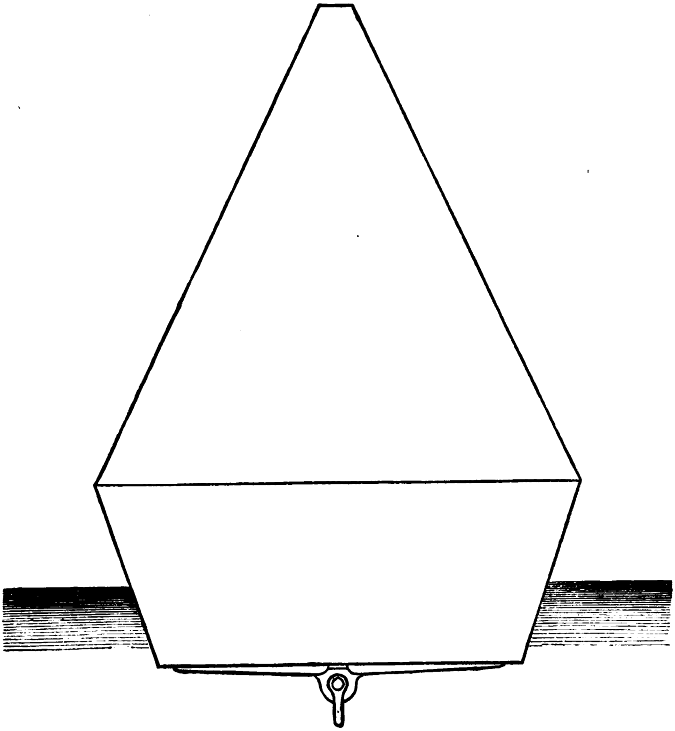
Fig. 1.



Channel Buoy; River Liffey.

It is very buoyant, and presents a far more conspicuous object than the barrel buoy, which it has superseded in the River Liffey. The bottom is either flat, or slightly coned. Another modification of the same form is represented in Fig. 2, (page 303,) which is an elevation of a channel buoy moored near the entrance of the River Liffey, and within the shelter of the walls which protect the harbour. The lower portion is a wrought-iron tub, 12 feet in diameter at the widest part, and 9 feet across the bottom. The conical superstructure is formed of wooden spars, arranged somewhat similar to those on the Liverpool Bell-boat. Flat-bottomed buoys are, however, ill-adapted for the open sea, as they are only slightly immersed, and are, consequently, easily 'boxed' about by the waves, which make them roll violently in rough weather; but this, perhaps, is of little consequence in the inner waters of a harbour.

Fig. 2.



Channel Buoy; River Liffey,

Want of conspicuousness and instability, one, or other of which defects characterise the buoys already described, have, in some measure, been remedied in Mr. Herbert's Cone-bottomed Buoy (Fig. 3, p. 304), a description of which has already been presented to the Institution.[1] It is well known, that the higher the centre of gravity of a free floating body is placed, the more sluggish will be the rolling motion, though its amount may be considerable. This was exemplified in the cruise of the 'Agamemnon,' with the Atlantic cable on board. The coil of cable on the upper deck raised the centre of gravity, and thus diminished the abruptness of her rolling, the angle of which is said to have exceeded 45°, in the terrible storm which she encountered. When vessels with a sharp rise of floor roll rapidly, the defect is said to be sometimes remedied

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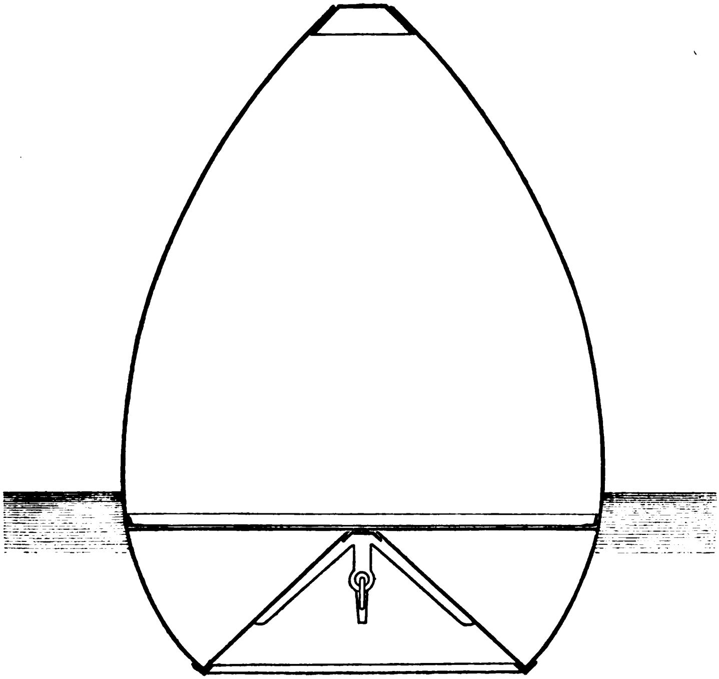
[1] *Vide* Minutes of Proceedings Inst. C.E, vol. xv., p. 1.

Fig. 3.



Cone-bottomed Buoy.

by stowing the ballast higher up. The adoption of this principle seems to have been the aim of the inventor of the Cone-bottomed Buoy. "The mooring chain," he states, "should be attached near to the centre of gravity and to the centre of the plane of flotation, which points should be nearly identical; and it was considered, that the easiest mode of attaining this, was by raising up and hollowing out the bottom of the buoy, to about the surface of the water, and near to the apex of the hollow cone thus formed, to attach the mooring cable."[1] Whatever advantage the inventor may have proposed by this arrangement, it has not been realised in practice, for the mooring chain is not attached either to the centre of gravity, or to the centre of the plane of flotation, but to a point nearly half-way between the plane of flotation and the lower edge of the buoy, and considerably below the centre of gravity. If it were fastened, as originally proposed, to the centre of the plane of flotation, the buoy would, under the influence of currents, incline strongly in the opposite direction, from the lateral pressure being below the centre of mooring, in place of being above it, as is usually the case.

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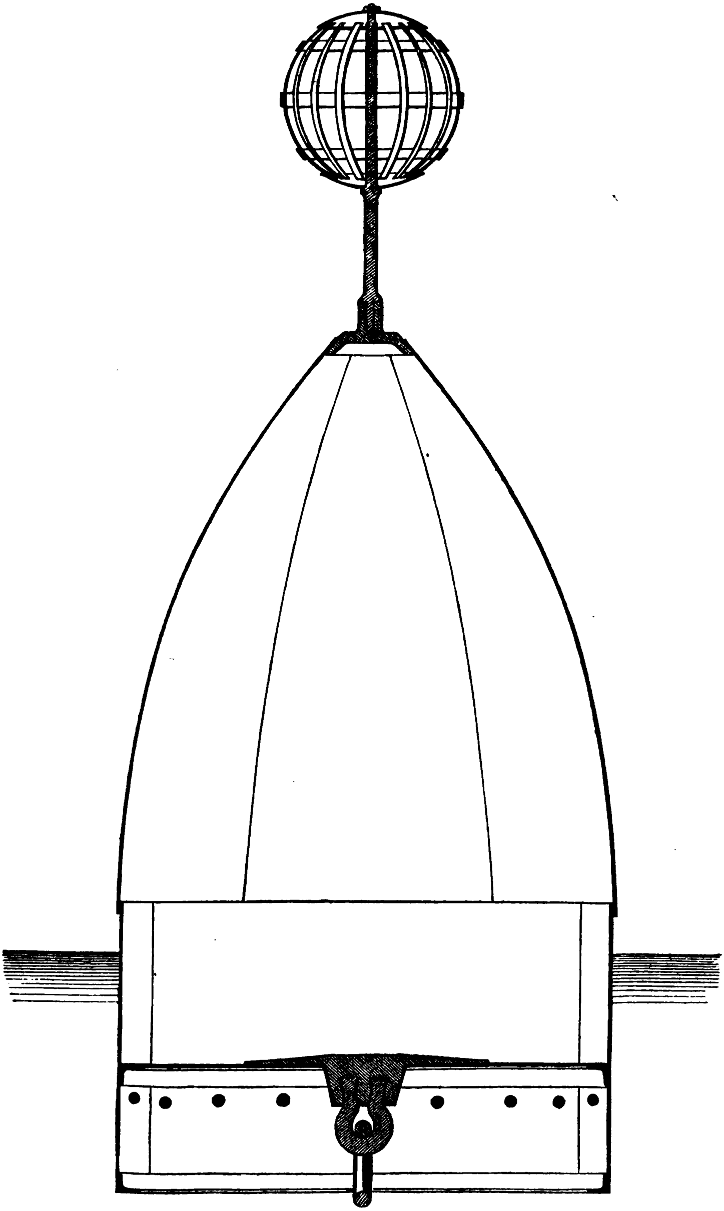
[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xv., pp. 1, 2.

In practical inquiries, the first step is to profit by the experience of others, and to ascertain what has been already done, under similar circumstances, to attain the desired result. In the case of a floating body, a ship obviously suggests itself for consideration. Now every sailor is aware, that additional keels, or bilge boards, tend to prevent ships of certain forms from rolling; and advantage has been taken of this in some of the lightships stationed round the coast, which have two keels on each side of the central keel, five in all, and their efficacy in steadying the vessel is due, doubtless, to the mass of water constrained to move along with the ship when she rolls, and which resists by its inertia any sudden movement of the vessel. A similar arrangement may be applied to a floating beacon, and the result is the Keel Buoy, represented in section, in Fig. 4; (page 306.) The superstructure may be of any of the ordinary forms, but the dome shape is preferred, as being the most conspicuous. It will be observed, that the sides are prolonged below the bottom, so as to form a circular keel, within which a large body of water is retained. Thus, a buoy 6 feet in diameter, with a keel of 18 inches, contains within the latter, a body of water exceeding a ton in weight, or a mass of water of nearly the same weight as the buoy. A buoy 8 feet in diameter, with a keel of 20 inches, contains upwards of 2 tons of water within the keel. A few air-holes are pierced in the keel, just underneath the bottom, for the purpose of letting the air escape on first floating the buoy. Thus, by a very simple arrangement, the floating mass is virtually doubled, or even further increased, if desirable; and the buoy is, consequently, less liable to be tossed about like a cork on the waves. Again, the bolt of the mooring chain, where it passes through the mooring ring, divides the surface exposed to lateral pressure, into equal, or nearly equal portions. Hence, the Keel Buoy floats erect in tideways, or rivers, however rapid; for equal pressure is exerted both above and below the centre of mooring. The keel also gives this buoy a much greater hold in the water, than is the case with other buoys. A sudden blow of a wave is resisted, as has been shown, by the inertia of the enclosed mass; but it is also resisted by the reaction of the water against the outside of the keel, especially when the buoy receives a sudden blow above the plane of flotation, a frequent occurrence in a chopping sea. Hence, the tendency to pitch is diminished.

Fig. 4.



Keel Buoy.

There is another advantage connected with the adoption of a keel. It acts as ballast placed in the best possible position for stability; and this is an important consideration, for it will be readily perceived, that the value of a beacon depends upon its having a lofty and conspicuous superstructure, which cannot be attained to the same extent in other buoys without the addition of ballast. Egg-bottomed buoys, for instance, do not float erect, unless either ballast or a heavy mooring chain be attached; and when the conical superstructure is replaced by a more conspicuous one, dome-shaped, the amount of ballast required has proved so serious a drawback, as to prevent this form being adopted. Even with ballast, the egg-bottomed buoy is easily inclined, owing to its shape under water. The Keel Buoy, in consequence of its peculiar form, may have a very lofty superstructure without endangering its stability. A buoy, 9 feet in height, (not including the keel,) and 6 feet in diameter, projects 7 feet 6 inches above the water; and in general, a Keel Buoy may have a superstructure 25 per cent. higher than that of other buoys of equal diameter, with the same configuration above water. A Keel Buoy of the size mentioned weighs 23½ cwt., while an egg-bottomed buoy of the same diameter weighs about 2 tons. The former will, however, even before the mooring chain is attached, support the weight of an ordinary man on the summit with only a slight inclination from the perpendicular; whereas the latter will, under similar circumstances, lie with the apex close to the water. The steadiness of the Keel Buoy is equally remarkable; for when in an experiment it was made to oscillate violently, by repeated synchronous pulls of a rope attached to the apex it ceased to roll after four or five oscillations.

The mooring ring adopted has been found to be simple and efficient. It is a button-shaped casting, which with the shank projects through an aperture in the wrought-iron bottom. As it is riveted to the inside of the bottom by a double row of rivets, the straining of the chain, however severe, can neither tear it away from the bottom, nor loosen the rivets. The ordinary form of mooring ring is a cross of wrought iron, riveted to the outside of the bottom; and it seems probable, that the disappearance of buoys may, occasionally, be attributed to the loosening of the rivets, under the ceaseless strain of the chain, which tends to produce leakage below the water line.

Turning from the arts of peace to those of war, another application of the keel suggests itself; namely, to floating batteries, whether revolving, or fixed. Here, stability, combined with freedom from rolling motion, is an essential quality, which may, it is believed, be attained by arrangements similar to those above described. In beacons of unusual size, or floating batteries, it may be found desirable to employ more than one keel, so as to divide the enclosed space into cells, whereby the water may be more surely made a part, as it were, of the floating mass.

The Author does not pretend to claim for floating bodies, constructed with keels as proposed, a total freedom from rolling. This is not to be expected, for there are certain waves which will cause any floating body to roll. What is claimed for, and has, it is believed, been attained in the Keel Buoy, is a greater freedom from abrupt motion than is possessed by other floating bodies having the same amount of displacement. A Keel Buoy will pitch less abruptly than any other buoy of the same diameter and weight, and it is only when these are equal, that a fair comparison can be instituted. If, for instance, a buoy is made very wide in proportion to its height, and with slight immersion, it will float upright, because it floats like a board on the surface of the water; but the stability thus gained is at the expense of facility in management. If, on the other hand, stability is sought for, not by breadth of beam but by ballasting the bottom, the buoy will not only be unwieldy, but expensive. Now the Keel Buoy is, as has been already stated, light, and therefore, easily handled; and moreover, it occupies no greater amount of space on deck, than is sufficient for it to stand on end; thus contrasting favourably with the can and the egg-bottomed buoys.

The Paper is illustrated by a series of diagrams, from which the woodcuts, (Figs. 1 to 4,) have been compiled.

Mr. **John Murray** said, it was evident, that the keel at the bottom must add to the stability of the structure, but he thought there should be some means of ready access to the top of the beacon, in case of shipwreck.

Mr. **Alexander Gordon** observed, that no facts were given in the Paper from which a judgment could be formed of the efficiency of the work. It did not appear to add much information to that already given in a previous Paper on the same subject, by Mr. Herbert,[1] which did not merely contain a proposition for the construction of buoys, and providing means for illuminating them at night, but it also gave the results of their action, after long experience, by the Corporation of the Trinity House. The circular casing to the bottom of the buoy, (Fig. 4, page 306,) was called a keel, but he thought the term inappropriate; it did not in any way resemble a keel, which, in light-ships, was a prolongation of the two bilge pieces, after the fashion of the lee board of a ship, with the view of preventing her making leeway under certain conditions. The buoys made upon the plan of Mr. Herbert, by Messrs. Brown, Lenox, and Co., were extensively employed by the Trinity Corporation, and had successfully fulfilled the purposes for which they were intended.

Mr. **Vignoles** deprecated the introduction of Papers of a purely theoretical character, not descriptive of works actually constructed. It was a wholesome rule, and he had known several instances in which valuable Papers had been rejected on that account, the object of the Institution being to discuss questions of fact, and not theories.

Mr. **Bruce** observed, that a Paper by Mr. Longridge,[2] (M. Inst. C.E.,) "On the Construction of Artillery," which created great interest in the Institution and throughout the country, had been recently read, although it did not relate to accomplished facts. There had also been, previously, a Paper by Mr. J. T. Harrison,[3] (M. Inst. C.E.,) "On the Drainage of the District South of the Thames," for which a premium had been awarded, although it was of a theoretical character. It was not therefore apparently the invariable practice of the Institution to confine the discussions to works which had been actually completed.

Mr. C. E. **Amos** observed, that in February, 1860, he had seen one of these buoys at the Ballast Office works, in Dublin, and it was furnished with a ladder, by which shipwrecked seamen could climb to the top.

Mr. **Giles** remarked, that ten years ago, he had seen a buoy in the Solent, near Southampton, which was also kept upright in the tideway, by being fitted with a keel, and it was provided with a ladder for reaching the top.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xv., p. i.

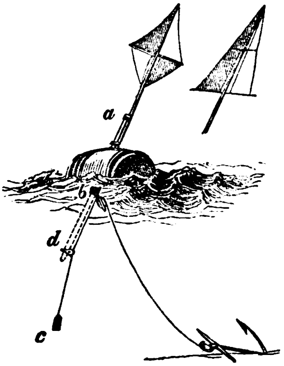
[2] *Ibid.*, vol. xix., p. 283.

[3] *Ibid.*, vol. xiii., p. 64.

Mr. G. Herbert also confirmed the fact of the buoy proposed by the Author having been in use. He did not perceive any essential difference between the buoy he had constructed and described in 1855, and that shown in Fig. 4, (page 306). In the first there was a cone, which he had adopted many years ago, because he considered it the strongest form of construction to resist the tugging of the mooring chain; in the other there was a flat diaphragm, or bottom, to which the chain was attached. If the cone were made open, instead of solid, there would not be the least difference between the two buoys. The buoy represented in Fig. 3, (page 304,) floated at a greater depth than the other, on account of the displacement occasioned by the cone.

In answer to an inquiry by the President, as to the results of experience with regard to his Cone-bottomed Buoys, during the last five years, Mr. Herbert said, that they had answered the purposes intended, in all the positions in which they had been placed, and that they were increased in number every year. The Cone-bottomed Buoy was extensively employed by the Trinity Corporation, as well as by Foreign Governments, and only two instances had occurred where they had been injured by breaking from their moorings, and then they were destroyed by being thrown among rocks. At Liverpool, buoys so constructed, 20 feet in diameter, and standing 20 feet above the water, safely rode out the late gales, and on no occasion, had there been, at that time, the slightest failure. They had proved so satisfactory, that all the ordinary buoys on that part of the coast, had been replaced by the Cone-bottomed Buoy.

Fig. 5.



Surveying Buoy.

Rear-Admiral Sir Edward Belcher said, that having to carry on a survey on the coast of Africa, out of sight of land, he had successfully employed the form of beacon shown in Fig. 5. A cask of 32 gallons, (and afterwards, one of 60 gallons,) was furnished with double staves, of greater width at the bung and opposite, as well as with double heads; and holes were bored through the bung and the opposite staves to admit of the passage of a spar $3\frac{1}{2}$ inches in diameter, which projected 3 feet on the upper side and 9 feet below. This spar, previously well parcelled and tarred, was driven firmly home, and cleated, to prevent its working out, and it was then caulked round the cleating. The larger end was furnished with irons for a topmast, 22 feet in length. Close to the cask, at *b*, a thimble was secured, through which the mooring cable passed, and another beneath, at *d*, where the cable was clove-hitched, parcelled, and its parts seized to the spar to prevent abrasion. At *c*, $2\frac{3}{4}$ cwt. of ballast were attached, at 3 fathoms below the cask. The buoys were moored taut in the line of the stream, and were provided with full-sized bunting flags. They were found to resist all weathers, and to maintain an erect position in very strong currents and tides; and they were so firm, and perpendicular, that he had been able to stand upon them and take angles with the sextant, even in rough weather. These buoys were, in some instances, placed at distances of five miles from each other, and the flags were so distinctly seen, as to be reflected by the sextant, and the angles between them could be accurately measured.

Mr. J. Cockburn Curtis had had extensive practice in the use of the beacons for marine surveying purposes, referred to by Admiral Sir Edward Belcher, and he did not remember a single instance in which they had failed in accuracy, notwithstanding the variable weather experienced during the survey. He did not attach so much importance to the shape of the buoy, as to the balancing of it, and bringing the centre of oscillation in accordance with the centre of flotation.

Mr. Gordon referred to the buoys used on Lake St. Peter, in Canada, which were constructed upon the plan of Mr. Atherton, (M. Inst. C.E.,) Chief Engineer of Woolwich Dockyard. It was found, that the buoys in the lake were sometimes carried away on the breaking up of the ice; Mr. Atherton, therefore, made each of them a frustum of an elongated cone, and he loaded them heavily, so that three-fourths of the larger end of the cone should be under water. The warmth of the sun relieved these iron buoys from the ice, and permitted them to right themselves, when the ice had floated away.

Mr. Hemans thought it was to be regretted, that the Author had not given a hollow foundation to his buoy. Mr. Hemans attached great importance to the hollow keel. The circular form permitted a firmer grasp to be taken of the water, on account of the quantity contained inside the segment, and it must, undoubtedly, contribute to the steadiness of the structure in the water. He hoped any experiments upon that form of construction, would be communicated to the Institution.

Mr. Stoney,—through the Secretary,—stated, that the system was not a mere theoretical invention. Seventeen keel buoys, most of which were first-class buoys, had been already constructed, for the Trinity Corporation, for the Ballast Board of Dublin, for Waterford Harbour, and for the Russian Government. The merits of the invention had been recognised by Captain Roberts, R.N., the Marine Inspector of the Ballast Board, who had placed two of these buoys on the coast of Wicklow, one on the Arklow Bank, one on the Codling Bank, and one on the coast of Down, on the Butter-Pladdy Reef. It had been contended, that it was incorrect to call the circular prolongation of the sides a keel, as no comparison could be fairly instituted between such a casing and the usual bilge pieces, and that this circular keel could not have the effect attributed to it by the Author. But this effect was not merely consistent with sound theory; it had been fully corroborated in practice. The first objection was based on a misconception of the action of bilge pieces and of the keel of the buoy, which both performed the same function, that of pressing against a mass of water, which by its inertia, steadied the floating body. The Keel Buoy had been also considered as a simple modification of Mr. Herbert's Cone-bottomed Buoy; whereas the principles on which the two inventions were based, and the mode in which they were carried into practice, were essentially different. The object of the former was stated to be, "that the mooring chain should be attached near to the centre of gravity and to the centre of the plane of flotation," and to attain it, a small conical hollow was formed, to the top of which the mooring chain was attached. But in the Keel Buoy, a flat metal plate, or keel, was added to steady the buoy; first, by its impact against the water; and secondly, by causing the mooring point to be at the centre of lateral pressure, which point could never coincide with the plane of flotation, and was, in practice, far below the centre of gravity. The cone had been supposed to be a stronger form than the flat bottom of the Keel Buoy, but though the downward pull of the chain was against the flat bottom, it was caused by the upward pressure of the water, which, at the same time, supported the bottom, and thus these forces counteracted each other; and therefore, if properly constructed, neither the cone, nor the flat bottom would give way. There was, however, some risk of the rivets which attached the mooring ring on the outside of the cone bottom, becoming loose and leaky from the continual jerking of the chain; whereas in the Keel Buoy, the mooring casting was like a flat button on the inside of the bottom, the shank only projecting through a central aperture. No amount of strain would cause it to leak, for it became tighter with every increase of strain. As compared with a Cone-bottomed Buoy of the same diameter, he claimed for the Keel Buoy the following advantages: first, it was stiffer; secondly, it was one-fourth more elevated out of the water, and consequently, far more conspicuous; and thirdly, it was more economical in cost, in the ratio of 3 to 5.

Mr. Bidder,—President,—observed, that this Paper was submitted to the Council in the usual manner, and was passed by them as proper to be read before the Institution. The reference made to Mr. Longridge's Paper, as justifying a departure from the rules, was not a happy illustration; because the guns of Sir William Armstrong, (M. Inst. C.E.,) Mr. Whitworth, (M Inst. C.E.,) and other inventors, had been, for the most part, practically tested by Government commissions, so far, at least, as they could be, apart from actual trial in war. It appeared, moreover, that the form of buoy described, had been constructed, and had been in operation. It was, however, so slight a modification of the form adopted by Mr. Herbert, that he did not think it entitled to be considered more than an improvement, which might be advantageous in certain situations. The keel was not likely to have the great effect, which the Author attributed to it. The keels of lightships were placed at a considerable distance from the centre of the vessel, and with lateral oscillation, the motion was very great. But this keel was in the direction of the axis, and would participate in the whole motion of the beacon.

March 12, 1861.

GEORGE PARKER BIDDER, President, in the Chair.

No. 1,037.—"On the North Sea; with Remarks on some of its Friths and Estuaries."[1] By JOHN MURRAY, M. Inst. C.E.

IN submitting a Paper on the North Sea, the Author wishes, at the same time, to bring under the notice of the Institution, the subject of charts, as now published by the best authorities. Many of them are founded on surveys executed with great care, and the drawings are well engraved; but it is difficult to understand them thoroughly, without attentive study. After a knowledge of the bed of a sea, or estuary is obtained, by a comparison of the soundings, so imperfect is the impression, that it is soon forgotten. A more lasting image is fixed on the mind, by even a cursory examination of geographical maps, on which the outlines of several states, or provinces are shown, by bordering them with different colours, or by tinting each separately. By adopting a similar method for charts, a more correct idea is obtained of the shoals, sandbanks, and channels. It is true, that in some of them, the lines of equal soundings are given over the most prominent banks, by dots and lines; but this plan is not carried out to any great extent, and the rest of the chart is frequently covered with little else than a mass of figures. If, in lieu of this system, the bottom were contoured from the original soundings, (these being omitted on the engraved copies,) and the contour lines marked with figures, in various places, indicative of their depth, it would be a great improvement. Again, if every 5 or 10 fathoms, were dotted, it would make a further distinction; and if a few different tints were passed over the surface between the dotted lines, and the deep sea engraved in shade, an excellent chart would be produced, at very little, if any, extra cost, and a correct notion would be conveyed, at a glance, of the bays on its verge, or of the estuaries into which the rivers discharge themselves.

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[1] The discussion upon this Paper occupied portions of four evenings, but an abstract of the whole is given consecutively.

The charts illustrating this Paper are contoured and coloured on this principle, which, for ordinary purposes, is, perhaps, carried to a greater extent than necessary. That of the North Sea was originally published by the Admiralty, in six sheets. It has long been out of use; but as the coast remains nearly unaltered, the Author has obliterated the soundings only, and contoured the bed from the more recent charts published by that authority. The contour lines show the position of the bottom, which is represented by the following tints:—

Between the land and	10 fathoms	yellow.
10 fathoms and	15 „	orange.
15 „	20 „	red.
20 „	25 „	purple.
25 „	30 „	blue.
Exceeding 30 „		in lighter to darker shades of blue stippled.

A preference is given to these tints from shallow to deep water, from being combinations of the three primary colours, and as they are distinct enough in themselves, to portray a difference in depth. After a little study, the mind becomes accustomed to the change, from ordinary charts; and generally the cause can be traced, which has produced the banks and deeps of the sea.

The western shores of Ireland, Scotland, and Norway, have a great similarity of outline. Each is rent into numerous inlets, creeks, and bays. Islands fringe the coast of Scotland, and its northern extremity terminates with the Orkney and Shetland groups. The Norwegian coast is bordered with countless rocks and small islands, and the mainland is penetrated by long, narrow, deep fiords, many of which are more than 30 miles in extent. The coast between the Lofoten Isles and Stadtland is struck with great fury by the waves; but between the latter and Stavanger, being sheltered by the Orkney and Shetland Isles, the waves act with less violence, and southward, trending off to the Naze, the coast is still less affected.

Northward of 62°, the sea, over its whole extent, is very deep; but the stream of flood splits off the coast of Norway in this latitude, one branch passing to the north, and the other to the south. The latter has scooped out, in an extraordinary manner, a long channel, as far as the Sleeve, at the mouth of the Baltic, from 20 to 40 miles in width, and from 200 to 300 fathoms, and in some places, 400 fathoms, in depth.

There is always an outward current from the Kattegat, along the southern coast of Norway, between Faerdar Island and the Naze; and so continuous is this stream, that within 2 or 3 leagues from the coast, it is rare to find it setting to the eastward.[1] It is, however, materially influenced by the weather in the North Sea.

The great stream of flood from the Atlantic, after traversing the western coast of Scotland, approaches the Orkney and Shetland Isles, from the north-west. It makes high water, at the full and change of the moon, on their western shores, between 9 and 10 o'clock. It passes onwards, and reaches Stadtland, in Norway, about 11 o'clock; the Skaw, or northern point of Jutland, at 12 o'clock; and Hammerfest, near the North Cape, at 1 o'clock.

The stream of flood passes eastward among the Shetland and Orkney Isles, and the strait between them; these streams, combining with that of the Pentland Frith, run southward along the coast of Scotland, making high water off Wick, at the full and change of the moon, at 11 o'clock. The great stream of flood, however, enters the North Sea between the coast of Norway and the Shetland Islands. Running southwards, it splits on Kinnaird Head and Rattray Point, throwing a branch westward into the Murray Frith; while the eastern portion of the great stream, pressed suddenly round those headlands, in passing onwards, forms the channel of the Buchan Deeps. Continuing its southerly course, it is checked in St. Andrew's Bay, and by the shoals off the coast of Fife, and it throws off branches into the Friths of Tay and Forth. In consequence of the Bell Rock, and other patches north of it, the southern stream of flood is divided; and the line of separation causes the formation of the shoal called the Long Forties, extending in a north-easterly direction from the Frith of Forth, for a distance of 100 nautical miles.

As the flood in the deep water is pressed forward with greater velocity than the streams which traverse the shallower water of the coast, the main current splits, off Dunbar and St. Abb's Head, causing one part to enter the Frith of Forth in a north-westerly direction. The other streams of flood running southward, parallel with the coast, within and outside of the Bell Rock, being checked by the shoals lying off the east nook of Fife, and the Isle of May, enter this great frith at a later period, and when the early flood has penetrated some considerable distance. The combined currents continue their course westward up this estuary, towards the northern side of the Isle of Inchkeith, and then, entering the strait of Queensferry, pass up the inner estuary of the Forth. The southern side of this fine frith, from the Bass Rock westward, thus becomes a great receptacle for the sands and other débris of the coast. It is high water, at the full and change of the moon:—

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[1] *Vide* "Sailing Directions for the Navigation of the North Sea." Seventh Edition. By J. S. Hobbs. 8vo. London, 1846. Page 193.

		Hrs.	Min.		Ft.	In.
Off Dunbar .	at	2	8,	with a tidal range of	14	6
At Leith .		2	17	„	16	6
At Queensferry		2	37	„	18	0

Proceeding southward from St. Abb's Head, the general outline of the coast is nearly straight, to the northern part of the county of York. Here the stream of flood encounters the coast projecting eastward from Redcar; and the tidal waters are, in consequence, heaped up in Tees Bay, where the tidal range of ordinary springs is 16½ feet; while at the mouths of the Tyne and Wear, it is not more than 14½ feet.

The great stream of flood continues to run south, parallĕl with the rocky coast of Yorkshire, meeting, off Whitby, the main stream coming due south from the deep water of the North Sea, which is here, however, reduced to 40 fathoms in depth. Both streams run towards Flamborough Head, making high water, at the full and change of the moon, at ½ past 4 o'clock, with a tidal range of 18 feet. A branch passes suddenly round this point to the westward, and sweeps Bridlington Bay and the low coast of Holderness, which, for a long time past, has been wasted away; another branch proceeds more directly for the mouth of the Humber; and the separation of these currents produces the great Smithwick sandbank. It is high water at the Spurn Point, on full and change, at 5 hours 26 minutes, attaining a range of 18 feet 9 inches; but the main stream takes a more south-easterly direction, and as the bed of the sea opposite the mouth of the Humber is reduced to 15 fathoms in depth, and southward of that contour line by extensive shoals lying off the coast of Norfolk,—over which are interspersed various prominent banks, such as the Outer Dowsing, the Dudgeon, and others,—the stream of flood is forced forward, scooping out, in its course, a channel called the Inner Silver Pit. Thence it runs into Lynn Deeps, and fills the Great Wash, into which the four rivers, Ouze, Nene, Welland, and Witham, have their outfall. At the Well, in Lynn Deeps, at the full and change of the moon, it is high water at 6 o'clock, and the range of the tide is 23 feet.

Another branch of the great stream of flood proceeds, in a south-easterly direction, towards the southern part of the North Sea, also scooping out channels, called the Sole and Coal Pits, and then continues to run south-east, between the Haddock, Leman, Ower, Svarte, and other long narrow banks, which much retard the velocity of the tidal stream. The consequence is, that high water in Yarmouth Roads, at full and change of the moon, takes place at ¼ past 9 o'clock, with a range of only 6 feet. The stream of flood then resumes its southerly course, hugging the coasts of Suffolk and Essex, until it falls into the estuary of the Thames, which it reaches about 12 o'clock; the tidal range of ordinary springs at the Nore being 15½ feet.

The distance from Kinnaird Head, in Scotland, to the east nook of Fife, is 90 nautical miles, and is traversed by the tidal wave in 1 hour 36 minutes, being at the rate of 56 miles per hour. From St. Abb's Head to Flamborough Head, a distance of 130 miles, the time occupied is 2 hours 22 minutes, or at the rate of 54 miles per hour; but, in the deeper water, from opposite Kinnaird Head to Flamborough Head, the distance being about 200 miles, the velocity is 60 miles per hour. From Flamborough Head to the Spurn Point, the tidal wave is propagated at the rate of 38 miles per hour; and thence to the Well, in Lynn Deeps, at the rate of 49 miles per hour. Over the shoal ground off the coast of Norfolk, the speed does not exceed 14 miles per hour; but from Yarmouth Roads to the mouth of the Thames, it attains a velocity of about 29 miles per hour.

Returning to the great stream of flood off Flamborough Head, the chart indicates (Plate 3), that the main set runs almost due east between the shoal ground on the coast of Norfolk, and the Outer Well Bank; and between the latter and the highest part of the Dogger Bank. It scours out in the former passage, a channel called the Outer Silver Pit, for a length of 50 to 60 nautical miles, its deepest part being 40 fathoms. Continuing onwards to the Texel, it throws off a branch southward, which proceeds towards the mouth of the Thames and the Schelde, where it arrives at 12 o'clock. On its passage, this current meets with the stream of flood issuing through the Straits of Dover, and the one neutralises the other.

The late Captain Hewett, R.N., when engaged on the survey of the North Sea, communicated to the British Association, in 1841, a Paper on this subject.[1] Being on board the ship 'Fairy,' in lat. 52° 27′ 30″ N., long. 3° 14′ 30″ E., at a point marked A, on the chart (Plate 3), on the 24th and 25th of August, 1840, he moored a long boat 'head and stern' in the direction of the strength of the stream, (N. E. and S.W.,) over the highest point of a shoal; and from another boat, which was allowed to drift past the former, a series of soundings was taken, keeping the line perpendicular until the summit of the overfall, in 18 fathoms 3 feet, was passed. This operation was repeated with the south-west stream, and on both days, under favourable circumstances;

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[1] *Vide* "Report of the Eleventh Meeting of the British Association for the Advancement of Science; held at Plymouth in July, 1841." 8vo. London, 1842. Transactions of the Sections, page 32.

on the 24th for seven hours, and on the 25th for twelve hours consecutively. During the whole of the time, the variation in the vertical rise of the water did not exceed 12 inches. Consequently, in this part of the North Sea, (as had been previously deduced by the Rev. Dr. Whewell, Master of Trinity College, Cambridge,) no rise and fall of the tide can exist; and therefore, the surface between the two opposite coasts must assume, near the shores, a convex form at low water, and a concave form at high water. The meeting of the tides causes extensive sands to be deposited on the Flemish and Dutch coasts, called the Broad Fourteens, and a kind of bar between them and the long narrow shoals, previously mentioned, off the coast of Norfolk, as at the mouth of a tidal river.

The great stream of flood from the Outer Silver Pit throws off another branch in a north-easterly direction, while the main set proceeds towards the mouths of the Weser and the Elbe, sweeping Friesland, and sometimes, acting on the coast in northerly gales, with great violence, and overflowing the adjacent country. There being no passage for the tidal water into the Baltic, the stream is forced in a northerly direction along the coast of Denmark, where it forms dangerous shoals. It impinges on an extensive reef off the northern point of Jutland; and in consequence of that reef, and the nearly constant out-set from the Baltic, the stream of tide is prevented from entering that inland sea. It, therefore, takes the name of an ebb tide, and runs in a north-easterly direction along with that current, until both unite with the flood entering the North Sea, between Norway and Scotland, to renew the course which it has just run.

It is high water, on the full and change of the moon, at the outer shoals off Texel at ½ past 6; and as the distance between this point and off Flamborough Head is 165 miles, the velocity of the tidal wave is at the rate of 30 miles per hour. Thence to Heligoland, it appears to be propagated at about the same rate; but northwards in the open sea, the velocity has not yet been ascertained. A few points carefully observed, on the excellent plan adopted by Captain Hewett, would clear up many discrepancies. The Author hopes, that measures will be taken, under the auspices of the Admiralty, for ascertaining the true course of the streams of flood and ebb, and the period of high water on the full and change of the moon, with the rise and fall of the tide off the German and Danish coasts, and between them and the tail of the Dogger Bank.

The débris of the littoral generally accumulates with off-shore winds, and is set in motion by the waves with on-shore gales, and is then carried along by the stream of flood. A great part of the east coasts of Scotland and England, as far south as the mouth of the Humber, is wasted away by the action of the sea; that of Scotland is carried into its bays and estuaries; but from the Frith of Forth to the Humber, the débris finds a resting place in the sea. The coarse particles, almost incessantly in motion, become, in time, reduced in size, and the finer are removed, and form shoals and banks elsewhere. The lighter sands are often carried by the flood tide into the mouths of the estuaries and rivers, forming deposits on their shores and beds, which again are scoured out, when freshes become the preponderating current. To this wasting away of the cliffs, must be added the clays, gravels, and other alluvial matter brought by different tributaries into the rivers, whence they are conveyed by land floods into the great receptacle of the ocean. The filling process is daily going on, with a never-failing supply from these sources. None is carried outwardly through the Straits of Dover, and none can pass northward between Norway and Scotland. Hence the gradual shoaling of this sea, and the silting up of the mouths of the Rhine and the Schelde. Hence, combined with the immense quantity of débris poured into the ocean from these rivers, the numerous sandbanks on the coast of Holland, many of which have long ago been converted by the industry of man into dry and fertile lands. Hence, also, the deposits at the mouth of the Baltic, forming the islands in the Kattegat, and indeed the whole country of Schleswig and Jutland.

Deposits of silt have taken place over the fen districts of Lincolnshire and Cambridgeshire. Much land has been excluded from the sea by embankments; and a great part of the coasts of Norfolk and Suffolk is now protected by dunes, or sandhills. In the time of the Saxons, an estuary extended up to Norwich, which city is represented, even in the thirteenth and fourteenth centuries, as being on the bank of an arm of the sea. The sands in the vicinity of Yarmouth were made habitable in the year 1008, since which time, they have stretched southward across the whole entrance of the ancient estuary. Much of it naturally silted up, and was, therefore, embanked and cultivated; but a great many fresh-water lakes still exist over the district, varying from 15 to 30 feet in depth, and from a few acres to as much as 1,200 acres in extent.[1] The mouth of the Yare has been, within the last five centuries, diverted about 4 miles to the south; and the outlet of the River Alde, which once had its confluence with the sea at Aldborough, has been gradually carried 10 miles distant to the south-west.

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[1] *Vide* "On the Geology of East Norfolk; &c." By R. C. Taylor. 8vo. London, 1827. Page 9 *et seq.*

The waters of the North Sea, having been the agent in causing deposits on so extensive a scale, seem, within historical times, to be making inroads, not only on many parts of England and Scotland, but nearly on the whole line of coast from the Schelde to the northern part of Jutland. Between the fourteenth and eighteenth centuries, parts of the islands of Walcheren and Beveland were swept away. In 1421, the tide made an irruption through the banks of the Meuse and the Waal, and formed a large sheet of water called the Bies Bosch, causing considerable damage; but much of it has been since redeemed. Not far from the Hague, the church of Scheveningen, now standing on the shore, was once in the middle of the village, half of the place having been overwhelmed in 1570. Katwyk was once at a considerable distance from the sea. In 1658 the island Orisant was annihilated. It is only by the aid of dunes and sandy deposits, skilfully held in their position by groynes and other means, that the coasts of Belgium and Holland are maintained. Petten, and several other places in the latter country, have been defended against the action of the sea, by embankments maintained with great care and at considerable expense. Successive inroads of the ocean began about the commencement of the thirteenth century, on the coast of Holland and Friesland. Lake Flevo, the bounds of which are, however, not exactly known, was formed by the overflowing of the Rhine. Frequent incursions of the sea consumed much of the low-lying district between Stavoren, in Friesland, and Medemblik, in Holland, till at length, about the year 1782, a breach was effected which swept away many towns, and submerged a large tract of country, on the present site of the Zuider Zee.

The islands stretching from the Texel to the mouth of the Elbe, including Heligoland and Neuwerk, the last a mere fortification on the sands at the mouth of the Elbe, are, probably, the relics of a tract once continuous. They have greatly diminished in size; and the number of them, in the time of Pliny, was twenty-three, where now only sixteen exist. In the year 800, Heligoland began to be acted on by the waves. In 1300, 1500, and 1649, other parts were swept away, till at last a small portion only, consisting of red marly rock, remained. Since 1700, a current has cut a navigable passage, and separated Sandy Island from Heligoland. Such destructive ravages are well recorded, and having taken place on a great length of coast, have carried much detritus into this sea, and formed its extensive banks.

The Author has now traced the sweeping course of the flood tide, acting upon the littoral of Scotland and England, wasting, during storms, nearly the whole line of coast, and carrying the débris southwards, along with its waters, from the Frith of Forth to the coast of Norfolk. It has been seen how the stream of flood, entering the Straits of Dover, checks the impetus of the northern tide, causing it to sweep past Friesland, until it encounters the coast of Denmark, which forces it in a northerly course, towards the deep water off the coast of Norway, where it meets the following flood, and recommences the circuit. The consequence of this immense whirl is the deposit of the Dogger Bank in the middle of the basin.

Its shallowest part lies directly off Flamborough Head, at the distance of about 60 nautical miles, with 8 fathoms of water upon it at low water. The area, within the contour of 10 fathoms, is 250 square nautical miles. Its length, within the contour of 15 fathoms, is about 75 miles, with an average breadth of 20 miles. The area comprised within the contour of 20 fathoms is upwards of 5,000 square nautical miles. The inference is, that if the tides continue to take their present course, they will, sooner or later, cause this extensive shoal to become an island, in the middle of the North Sea.

It would be tedious to make any lengthened remarks as to the ebb tide. Its stream is, generally, the reverse of the other, and can readily be ascertained by a study of the charts. In certain places peculiarities occur, but they do not require notice. It will be more interesting, to consider the effects produced by the action of the tide amidst the islands and straits in the north of Scotland, and on the mouths of some of its estuaries.

In the Pentland Frith, and amongst the Orkney Isles, ordinary spring tides rise about 8 feet; but sometimes, with west and south-west winds, the range becomes 14 feet, while with north-east, east, and south-east winds, it is reduced to 6 feet. The run of the ebb in the frith is perceived near the land on each side for some time, often as much as three hours, sooner than in the middle. When the stream runs strong, the current is rough, and breaks as if passing over a shoal, while the sea on each side remains smooth. According to Captain Hewett's observations, the stream, in ordinary spring tides, runs 10½ miles per hour, and during violent storms, at a still greater rate. Captain Otter, during his survey,[1] measured a velocity, during the ebb tide, of 10·6 nautical, or 12¼ statute miles per hour. At the Orkney Isles, the maximum velocity of spring tides in the channels, is about 9 nautical miles per hour. It acquires a considerable degree of strength in less than an hour after slack water, and it becomes most rapid between the third and fourth hours of the tide. Amidst these islands, there are channels in which the waves swell to an extraordinary height during ebb tide only, and break with violence, even in calm weather; while during flood these places are as smooth as elsewhere. These are called 'rösts;' they are carefully avoided at one part of the tide, whilst they pass unnoticed at others. A röst rages most with a spring tide and a strong west wind.

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[1] *Vide* The Admiralty Chart of the Frith of Pentland; the "North Sea Pilot, Part II." 8vo. London, 1857; and "Tide Tables for the English and Irish Ports, for the year 1861." 8vo. London, 1860. Page 113 *et seq.*

The Author will now refer to the enlarged Chart (Plate 3^A,) of the Murray Frith, contoured and coloured.

The distance between Noss Head, on the coast of Caithness, to Kinnaird Head, the north-eastern point of Aberdeenshire, is 57 nautical miles. The depth of this bay, to the bar of the Frith of Dornoch, is 43 miles, and to Fort George, at the mouth of the Frith of Inverness, 57½ miles. One part of the stream of flood in this bay, has its origin in the Pentland Frith, and the several in-runs through the Orkney Islands; which streams, meeting off Noss Head, carry forward the flood in a south-westerly direction. The middle of this stream is situated about 4 nautical miles from the coast of Wick, where the depth is about 40 fathoms, gradually shoaling to 30 fathoms at the southern part of the Smith Bank. The detritus of the coast is carried forward by this branch of the flood tide, along the shores of Caithness and Sutherland, into the smaller bay formed by the headland of Tarbet Ness, whence issues the Frith of Dornoch.

The distance between Tarbet Ness and Dunrobin Point is 9½ statute miles, while the distance between Dornoch Point and White Ness is not quite 2½ miles; and about midway between lines drawn from these points lies the bar, with 11 feet of water upon it at spring ebbs, and a range of tide of 12 to 13 feet. The bar takes the shape of a half-moon, and landward of it, on the north side, is the long sandbank called Gizzing Briggs, and on the south side the extensive flat sands of White Ness. A longitudinal section of the Frith of Dornoch, from the deep water of the sea to Bonar Bridge, taken from the Admiralty Chart, is given in Plate 3^B. The tide extends upwards through the Kyle of Sutherland to the confluence of the Rivers Oikel and Cassely, 12½ miles above Bonar Bridge. It was ascertained by Mr. David Stevenson, (M. Inst. C.E.), in 1842, that the low water of the sea stood at the same level throughout the frith, to a point distant about 60 yards above Bonar Quarry, 17 statute miles from the bar. Between that point of meeting, or intersection with the descending fresh water and Bonar Bridge, a distance of 1,700 yards, the low-water line of the river at that bridge, stood 6 feet 6 inches higher than low water at the quarry, giving an average slope of 6·73 feet per mile.

Mr. Stevenson fixed gauges, accurately levelled, at Portmahomack without the bar, and within the estuary at Meikle Ferry, Bonar

Quarry, and Bonar Bridge. By his observations, it was found, that the range of a spring tide was, at the former place, 12 feet 8 inches, at Meikle Ferry 13 feet 5 inches, at Bonar Quarry 13 feet 8 inches, and at Bonar Bridge 6 feet 10 inches; the less rise at the latter being caused by the slope of the descending stream. He also found, that the first appearance of the flood tide at Portmaholmack and Meikle Ferry, a distance of 11 statute miles, was traversed in 30 minutes, giving a propagation to the tidal wave of 22 miles per hour. Between Meikle Ferry and Bonar Quarry, a distance of 8 miles, the transit of the wave occupied 65 minutes, being a velocity of nearly 7·4 miles per hour. Between the Quarry and Bonar Bridge, a distance of one mile, the transit was reduced to 1½ hour, giving a velocity of only ⅔rds of a mile per hour. These diminished rates of propagation of the tidal wave arise from the contractions of the estuary, the less depth of its channel, and the reduced sectional profiles from the mouth upwards.

The watershed of the rivers which fall into the frith, is nearly encompassed with mountains, of the average height of 3,254 feet above the level of the sea. The area drained by the River Oikel and its tributaries, comprising 307 square miles, has a rapid declivity from the high lands, with no lochs, except the Kyle of Sutherland, to regulate the discharge of the floods. The district of Loch Shin comprises 159 square miles. The lower area, of 109 square miles, is of more gentle descent, and is drained into the frith below Bonar Bridge.

The Author has been favoured, through Mr. Gibb, (M. Inst. C.E.,) of Aberdeen, with the rainfall taken at that place, for twenty-three years, from 1833 to 1859, with certain exceptions arising from incomplete returns, and the average amounts to 25¼ inches per annum. The average annual rainfall at Arbroath, during 1855, 1856, and 1857, was 25·6 inches. At Elgin, in the same years, it was 24·2 inches. Taking the rainfall at Aberdeen at 25¼ inches, at a level of 100 feet above the level of the sea, and applying the formula of Mr. Hawksley, (M. Inst. C.E.,) of 2½ per cent. additional for every 100 feet in height, the rainfall on the mountains, over the watershed of the upper streams, would be 45¾ inches; and deducting from this 22½ per cent. for loss from evaporation, absorption, &c., there remain about 36 inches to flow off the ground throughout the year. This amount is equal to 160 cubic feet per minute per square mile; and on 466 square miles it will yield 74,560 cubic feet per minute, as the ordinary discharge of the River Oikel at Bonar Bridge. This is corroborated by the fall of the river between Bonar Bridge and Bonar Quarry, as given by Mr. Stevenson; viz.: 6 feet 9 inches in the distance of one mile; for, assuming the low water width to be 300 feet, with an average depth of 1 foot 9 inches, the discharge is calculated to be 72,800 cubic feet per minute. Taking 120 cubic feet per minute per square mile, as the ordinary drainage of the lower district, by its area of 109 square miles, there is a discharge from these streams of 13,080 cubic feet per minute; making a collective drainage into the frith, at ordinary times, of 3,246 cubic yards per minute, which, as will appear hereafter, is the $\frac{1}{125}$th part of its total discharge. But in the drought of summer, the whole of the fresh-water streams are insignificant, in comparison with the capacity of the estuary below Bonar Bridge, and the Kyle of Sutherland above it.

By the Admiralty Chart of this frith, its length from a line joining Dornoch Point and White Ness to Bonar Bridge, is 14 miles. The high-water area, at spring tides, between these points, measures upwards of 21 square miles, and at low water upwards of 8½ miles. The Kyle of Sutherland is 12½ miles in length from Bonar Bridge to the confluence of the Rivers Oikel and Cassely, and its area at high water is 5⅔ square miles, making the extent of the whole estuary nearly 27 square miles.

Mr. Stevenson ascertained, that at Meikle Ferry, the surface velocity of the ebb tide was 2·55 miles per hour: this is presumed to be its maximum rate, and therefore, about the time of half ebb. The transverse section of the frith at this point is shown in Plate 3^{B}, taken from the Admiralty Chart. Under the line of half tide its area is 40,985 square feet; consequently, the discharge from the upper part of the estuary, including nearly all the streams, would average about 113,544 cubic yards per minute, throughout the period of the ebb. The area of the frith below Meikle Ferry and a line connecting Dornoch Point and White Ness measures, on the Admiralty Chart, 11,898,780 square yards at high water, and 5,022,470 square yards at low water; consequently, the contents of this part of the estuary amount to about 111,754,400 cubic yards. Assuming the duration of the ebb as 6 hours 22 minutes, the total quantity of water passing out of the frith at its mouth, will average 406,094 cubic yards per minute. Now, the area of the Section extending from Dornoch Point to White Ness, at the period of half ebb, is 140,138 square feet, and, consequently, the maximum velocity through this section would be 2·648 miles per hour. In the open sea, therefore, over the bar situated upwards of 4 miles from Dornoch Point, the maximum velocity of the ebb cannot exceed the rate of one mile per hour.

Notwithstanding this gentle velocity of the stream of ebb out of the estuary, with the duration of flood and ebb nearly alike, conditions under which it has been contended by some Authors, no bar could be produced, there is one as well defined as in any tidal river. Others are of opinion, that bars are composed of matter held in suspension by the waters of the rivers, and are deposited when the current meets the still water of the ocean. But no great quantity of débris is carried down the rivers which fall into this estuary ; at all events, none to produce a bar of sand like the one in question. Deposits do take place for a short distance below Bonar Bridge, and are due to alluvial matter. But the sand spit at Meikle Ferry, and that opposite to it, with others below them, can be produced from no other cause than the in-draught of the sea carrying the finer sands up the estuary, where they are deposited, and being acted upon by the ebb, take the forms represented on the chart. A vast mass of sands extends seaward of Dornoch Point on the north of the channel, and seaward of White Ness. Other sands of great extent bound its southern side. Violent on-shore gales draw off from the shores, as well as raise from the bottom, the sands and other matter accumulated during calm weather and westerly winds. The sweep of the flood tide carries along the detritus, and conveys some of it into the seaward part of the estuary, where it is deposited in its bed and on its shores. Other portions form a beach across its mouth, which would effectually bar it, if there were no tidal currents to maintain a channel. What is carried into the estuary on the flood with on-shore gales, is on their cessation swept away, in the course of time, by the outset of the ebb, and returned to the ocean. The bar of this frith is exposed to the full force of a gale from the north-east, and at such periods is found to be in its worst condition. Under-currents on the flood tide, when subjected to the stroke of the sea, tend to increase its height, and the Author attributes its formation to this cause more than to any other ; for the bar is in its best state in calm weather, after a continuance of land floods, especially if these are accompanied with strong spring ebbs.

Circumstances would be very different if, by any possibility, the waters of the estuary had an outlet to sea, through the neck of land at Portmaholmack, south of Tarbet Ness. In this case, the bar would be formed in deep water, considerably beyond the line of coast, and the whole tract between Tarbet Ness and the coast opposite, comprising an area of several square miles, would necessarily silt up. No such scheme, however, is recommended, because it would be an expensive operation to cut through the neck of land, and especially the part under water, even if the materials were applied to assist in partially closing the present mouth of the frith ; the large area reclaimed, being a tract of sand, would long remain worthless, and land, moreover, in that part of the country, is of small value. The subject is only mentioned to point out the great changes which, under more favourable circumstances of locality, might take place, by carrying out such a project, for the purpose of obtaining a deep-water entrance and commodious harbour within it. But here, no such harbour of refuge is required, for the superior advantages of the adjacent Frith of Cromarty are well known and appreciated.

A second part of the flood tide enters the Murray Frith from the deep water of the North Sea, and the consequence of the meeting of this stream with the other formerly mentioned, is an extensive deposit of sand between them called the Smith Bank. The stream passes onwards to the Frith of Cromarty.

A third part of the flood, and evidently the most powerful, also enters the Murray Frith from the deep water, running parallel with the coast from Kinnaird Head westward, filling with tidal water the Frith of Inverness, and carrying along with it the detritus of about 80 statute miles of coast. The consequence of this sweep of tide has been a large increase of land, extending from Burgh Head to near the mouth of the River Ness, a distance of 32 miles; and the accumulation has, in time, contracted the mouth of the frith, by the prolongation of a spit of sand, at the extremity of which stands Fort George. Another spit has likewise been formed in front of Fortrose, called Chanonry Point, on which a lighthouse is placed. In consequence of these deposits, the entrance to the Frith of Inverness is now reduced to 1,400 yards in width, with a depth of 23 fathoms at low-water spring-tides. Through this comparatively narrow, but deep channel, both the streams of flood and ebb run with considerable velocity; but the Author has been unable to obtain any correct data, on which calculations could be based, as to the amount of water passing into and out of this estuary. In former times, the mouth must have been as much exposed to the action of the waves as the Dornoch Frith, having a similar bar outside: none, however, now exists, for the main stream of flood running westward and south of the Riff Bank, enters the frith almost at a right angle round Fort George, while the first set of the ebb makes its escape to sea northward of that bank, parallel with the coast of Ross, uniting soon afterwards, with the outset from the Frith of Cromarty.

As a matter of comparison between the entrance of this frith and those adjacent, it is considered essential to give a longitudinal section (Plate 3^{B}) of the lower part of it, showing its connection with the deep water and the sea. The bottom, south of the Riff Bank, which is etched, is traversed by the main set of the flood. The bottom, dotted, represents the channel north of that bank, along which the first of the ebb takes its course. At a later period of the ebb, it is almost unnecessary to say, that the water makes its escape to sea through both channels, but it is well to draw attention to the fact, that the flood channel is considerably deeper than the other.

The coast of Ross is well defined, extending nearly in a straight line for about 30 statute miles, from Tarbet Ness to the mouth of the River Ness. This line is further continued nearly straight, and equally prominent, to Loch Eil, in Argyllshire, a distance of about 60 miles; and in this valley is situated Lochs Ness, Oich, and Lochy, now connected by a chain of locks and forming the Caledonian Canal. It is worthy of remark, that the maximum depth of Loch Ness is 129 fathoms, while the greatest depth in the Frith of Inverness is only 10 fathoms; and over the whole of the Murray Frith, and even beyond it in the open sea, the depth does not exceed 50 fathoms, except along the coast of Elgin, where a channel is maintained 100 fathoms in depth: proving the great extent of the silting up of these estuaries.

The entrance to the Frith of Cromarty lies about due west, through a gorge between the headlands called the Suters, 15 statute miles south of Tarbet Ness. The average width, at high water, is about 1,600 yards, the maximum depth 28 fathoms, and the length of the gorge is upwards of a mile and a half, from the line of coast to the Ness, where the small tidal harbour of Cromarty is situated. After passing the strait, the frith opens out into a wide expanse, having Nigg Bay on the north, and Udale Bay on the south, with ample width and depth in the centre for a large fleet. The distance from Cromarty to Invergordon is upwards of 4 miles, and the area of this sheet of water is nearly 18 square miles. The length of the frith to Conan Bridge, the extremity of the tidal flow, is about 20 miles; its area at high-water spring-tides is 32½ square miles, and at low water nearly 16 square miles. The long, narrow, and deep entrance of this frith is well protected by the Suters; and the rapidity of the regular currents through it, causes a vessel to steer well and steadily when seeking shelter. At the termination of the strait, the estuary expands, which allows the swell of the waves to be dispersed, a matter of great importance in a haven for shipping adjacent to deep water outside. The entrance from the sea is well defined in the distance, by Ben Wyvis, or the Hill of Storms, 3,246 feet above the level of the sea; hence this frith constitutes a fine harbour of refuge, and the only one on this part of the coast of Scotland.

The watershed comprises an area of 334 square miles, and is drained by the River Conan and its tributaries. It is bounded on the north, west, and south, by several lofty mountains. Many small lochs are interspersed over its surface, but the streams descend with considerable rapidity. The area on each side of the waters of the frith comprises 226 square miles, and is drained by various small streams, which sometimes swell into torrents. Taking the ordinary drainage at 120 cubic feet per minute per square mile, over 334 square miles, it would give 40,280 cubic feet per minute, as the yield of the river at Conan Bridge; and in consequence of the rapid declivity of the bed of this river and its tributaries, with the absence of any great natural lake to act as a regulator, it would appear, that five times that amount, or 201,400 cubic feet per minute, would be the discharge of floods, while $\frac{1}{5}$th of the ordinary discharge, or 8,056 cubic feet per minute, would be the summer yield of the river during drought. These figures are approximative, but they are borne out by the statements of Mr. Alan Stevenson, who measured the streams in 1837. According to these measurements, the summer discharge of the river, at Conan Bridge, was 7,969 cubic feet per minute, which quantity was calculated by him as $\frac{1}{1541}$th part of the total discharge from the frith in twelve hours. Mr. Stevenson also ascertained, that the same river discharged during floods, 216,589 cubic feet per minute; which he calculated as being $\frac{1}{57}$th part of the total discharge from the frith in twelve hours. The mean of these statements makes the contents of the estuary to be 328,344,582 cubic yards.

The surface velocity of both flood and ebb through the entrance could not account, in Mr. Stevenson's opinion, for the quantity of water actually passing into and out of the estuary. This led him to observe the under-currents, by means of submerged floats; and he found, that during flood, the surface velocity was 1·8 mile per hour, while at the depth of 50 feet, the velocity was not less than 4 miles per hour. During the ebb, the surface velocity was 2·7 miles per hour, and at 50 feet below the surface, the velocity was not less than 4½ miles per hour. It is to be regretted, that the experiments were not continued to greater depths, and at regular intervals from the surface downwards; so that the true curve might have been ascertained, and the point of maximum velocity determined, both on flood and ebb. These under-currents flowing into and out of the Frith of Cromarty are interesting facts, and deserve further investigation. Reference has therefore been made to the Admiralty Chart, which has been contoured and coloured according to the soundings marked upon it. A longitudinal section has thus been obtained (Plate 3^{B}) extending from the deep water outside, through the gorge between the Suters, to the extremity of the tidal flow at Conan Bridge. Transverse sections have also been formed from the same chart (Nos. 1, 2, 3, 4, and 5) between the Suters and the Ness of Cromarty, of which the minimum is the central section No. 3.

By this chart, the area of the frith at high water, between the minimum section No. 3 and Conan Bridge, measures 101,213,333 square yards, and at low water 49,398,639 square yards; these numbers multiplied by the rise of tide at the entrance, 14 feet, will give 351,427,935 cubic yards for the contents of the estuary above the level of low-water spring-tides. Taking the surface velocity of the flood tide at the gorge to be 1·8 mile per hour, this, with the area and wetted perimeter of the minimum section, will give the fall due to the surface velocity at the time of half-flood; and assuming the surface at high water to be parallel with this line upwards, (but which must actually be in excess,) the cubic contents to be deducted from the estuary, in consequence of the high-water surface not being level throughout the frith at one time, are approximately obtained. This quantity is found to be 17,153,932 cubic yards. There are, however, to be added the waters of the River Conan, which in the drought of summer may be taken at 7,969 cubic feet per minute, and those of the other streams draining into the estuary at the rate of 5,392 cubic feet per minute, making the total discharge from the frith amount to 334,463,185 cubic yards, or $\frac{1}{54}$th part more than the quantity given by Mr. Stevenson. Calling the duration of ebb 6 hours 22 minutes, 875,558 cubic yards per minute are obtained, as the mean discharge throughout the ebb. Taking now the surface velocity on the ebb at the gorge between the Suters, as 2·7 miles per hour, and at 50 feet deep, 4·5 miles per hour, the mean for that depth is 316·8 feet per minute. Then one-third of this for the mean velocity throughout the period of ebb, multiplied by the several sectional areas 50 feet deep, (under the line of half-ebb,) gives 627,009 cubic yards per minute; which, deducted from the total discharge, will leave 248,549 cubic yards to pass through the Suters beneath the 50-feet line. The velocity at that depth being 4·5 miles per hour, and assuming the bottom velocity to be nothing, then the mean is 108 feet per minute, and one-third of this throughout the period of ebb, will give 66 feet per minute. Hence, the sectional areas under the 50-feet line in motion will be 101,694 square feet, which gives the line A B represented on the different cross sections.[1] Therefore, on

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[1] The calculation stands thus:—

The velocity at the surface = 2·7 miles per hour = 237·6 ft. per minute.
„ at 50 ft. below = 4·5 „ = 396·0 „
2) 633·6
316·8 Half tide.
0·0 High water.
0·0 Low water.
3) 316·8
105·6 Mean velocity.
The minimum sectional area to 50 feet under half tide = 160,345 sq. feet.

[Hence

the ebb, with the summer discharge from the rivers, all below that line is stagnant water.

	Feet.	Inches.	
The line A B on Section No. 1 =	79	2	Above the bottom in the middle of the Section.
„ „ „ 2 =	82	3	
„ „ „ 3 =	11	0	
„ „ „ 4 =	57	3	
„ „ „ 5 =	31	5	

The mean is 52 feet, and from thence to the surface at half-tide, being 99 feet, gives, on an average, about one-third of the total depth as stagnant in the gorge between the Suters.

Secondly, working out this question in the same way, during the discharge of freshes, it is found that, in the minimum section No. 3, the whole water is in motion, but with a very slight velocity at the bottom. It was deemed unnecessary to ascertain the depth of stagnant water in the other sections, it being evident, that the area would be considerable.

Thirdly, assuming the flood spring-tide to have a duration of 6 hours 4 minutes, the surface velocity at the gorge, which is 1·8 mile per hour, and at the depth of 50 feet, 4 miles per hour, gives a mean of 255·2 feet per minute. Working out the question in a similar manner as before, it is found that, in the minimum section No. 3, the whole of the water is in motion, with a velocity of 93 feet per minute at the bottom; but the velocity would be considerably diminished in the other sections, and in some of them a portion of the lower part would still remain stagnant.

Hence 160,315 × 105·6 = 16,929,264 cubic feet per minute.
The total discharge is 875,558 cubic yds. = 23,640,066 „ „

The remaining quantity = 6,710,802 „ „

Now the velocity at 50 feet below the surface = 396 feet per minute.
„ at the bottom = 0

2) 396

198 Half tide.
0 High water.
0 Low water.

3) 198

66 Mean velocity.

Then $\frac{6,710,802}{66}$ = 101,694 Sectional area in motion under the 50 ft.-line.
160,315 Ditto ditto above ditto.
3,791 Ditto Stagnant.

265,800 Total.

It is evident, that the bottom of all the sections must, at times, be acted on, otherwise the gorge would be partially filled up. This action can be produced, therefore, only at extraordinary spring tides, such as those which occur at the equinoxes. But for want of data as to the rate of the currents at such times, no definite conclusion can be arrived at, as to the velocity in each section at the bottom.

As a matter of comparison, however, it may be assumed, that the upper velocities on the ebb are the same as at ordinary spring tides; and on this assumption it is found, that in the maximum section No. 2, the whole water would be in motion, with a velocity at the bottom of 22 feet per minute, or ¼ of a mile per hour throughout the ebb; and hence the velocity at the bottom at half-ebb would be ¾ of a mile per hour.

Lastly, with a similar equinoctial spring tide flowing into the estuary, it is calculated, that the water in the whole of the sections would be in motion, and that in the maximum section No. 2, the velocity at the bottom would be 90 feet per minute, or one mile per hour throughout the flood; and hence the greatest velocity at the bottom at half-flood would be 3 miles per hour. These calculations are exhibited in the form of a diagram, (Plate 3ᴮ,) which bring them readily to view. They show that in the Frith of Cromarty, the action of the flood tide is, by far, the preponderating force.

The bar, deep as it may be under low water, is no less a most formidable bank beyond the line of the coast, and the flood tide, after passing it, pitches into a pool, then runs through the minimum section in the gorge, pitches and rises again, and continues this undulatory motion for several miles up the estuary. This will, no doubt, recall to many, the theory of Emy, named by him the 'flots de fond,' or action of the waves on the bottom. A very similar effect is produced in the Dornoch Frith. It is the same in the lower reaches of the Tay, Tyne, Humber, Thames, Mersey, and other rivers. It is met with under still greater depths in the open sea, as in Hurd's Deep in the English Channel; at the northern and southern entrances of the Irish Sea, in the former of which there exists a channel upwards of 20 miles in length, 1½ mile in width, and 25 fathoms deep. The current in the Straits of Dover is another example; and in the North Sea, the Inner and Outer Silver Pits, with others off the coast of Norfolk, have been previously noticed, as well as the long deep channel skirting the coast of Norway, from the latitude of 62° to the Sleeve at the mouth of the Baltic. Another deep channel is clearly defined on the Admiralty Chart parallel with the coast of Aberdeen, at the entrance of the Murray Frith. It is about 15 miles in length, about 1½ mile in breadth, and 100 fathoms in depth; while the deepest part of the adjacent open sea does not exceed 50 fathoms.

It must be evident, that the flood only can produce these depths, for the waters of the ebb can have no such effect. It is no doubt caused by tidal action, accompanied by waves, and under-currents from the deep water of the open sea, acting on the bottom, diminished in force and perhaps imperceptible at the surface.

The formation of the bar, or great bank of sand, at the entrance of the Frith of Cromarty, is situated beyond the line of coast, and its formation may be attributed to the under-currents of both flood and ebb, subjected to the stroke of the sea during stormy weather. The shallowest part of it lies to the northward, which is the direct course of the ebb; and if the maintenance of the channel were dependent on the scouring power of that current, this ought to be the deepest part of it; whereas the southern channel open to the course of the flood tide is deeper than the other. The same effect is produced in many rivers, more, or less considerable, in proportion to their breadth and especially their depth at the confluence with the sea. If the river be in flood, after excessive rain, the fresh water apparently overpowers the force of the flood tide, and in many cases throughout nearly its duration; but at such times, if properly examined, it will be found, that an under-current of salt water will be running inwards from the sea near the bottom, arising from its greater specific gravity and the tidal action exerted upon it from the ocean. If the fresh water be not so powerful, but yet muddy in character, the current from the sea is often clearly defined, making its way inwards like a long tapering wedge, but which beneath is spread along the bottom from side to side of the channel, until it quite overpowers the descending stream, when the whole of the section becomes salt water.

Before concluding, it may be well to consider, what effect would be produced by the erection of a pier at right angles with the coast, and connected with the South Suter. It would, in the opinion of the Author, encourage the flood to enter the frith at an earlier period of the tide; it would also, by intercepting its course, cause the flood current to run across the middle of the bar; and the consequence would be one deep channel for both the flood and the ebb. The flood tide entering earlier than at present, would also continue longer, and the momentum given to it would encourage a larger quantity of tidal water to run up the estuary, and to attain a greater elevation at the extremity of its flow; and this increase of quantity on its reflux would exert a more powerful scour on the channel downwards. The addition of a pier to such an estuary is, doubtless, unnecessary, but an Engineer should consider a subject of this kind in all its bearings; as it is well known what beneficial effects have been produced in other harbours, by the judicious application of such a work.

In these three contiguous estuaries, some useful information may be obtained, in the designing of marine works:—

1st. In the Frith of Dornoch, the bar is exposed to the full force of the sea, and no works of an ordinary character could get rid of it in its present situation.

2ndly. The bar has been removed from the Frith of Inverness by natural means, well worthy of mature study.

3dly. The Frith of Cromarty has, from the peculiar and happily-placed position of its entrance, a bar it is true; but submerged at such a depth as, practically, to be of no inconvenience.

It was the intention of the Author to have continued his remarks on some of the harbours and rivers of the coast of Scotland and England; but the great length of this Paper has precluded him from doing so. If permitted, however, he may hereafter obtain an opportunity of again drawing the attention of the Members to the subject; as well as to the Southern part of the North Sea, and its connection with the English Channel.

The Paper is illustrated by plans, diagrams, and maps, from which Plates 3, 3^A, and 3^B, have been compiled.

PLATE 3, VOL. XX.

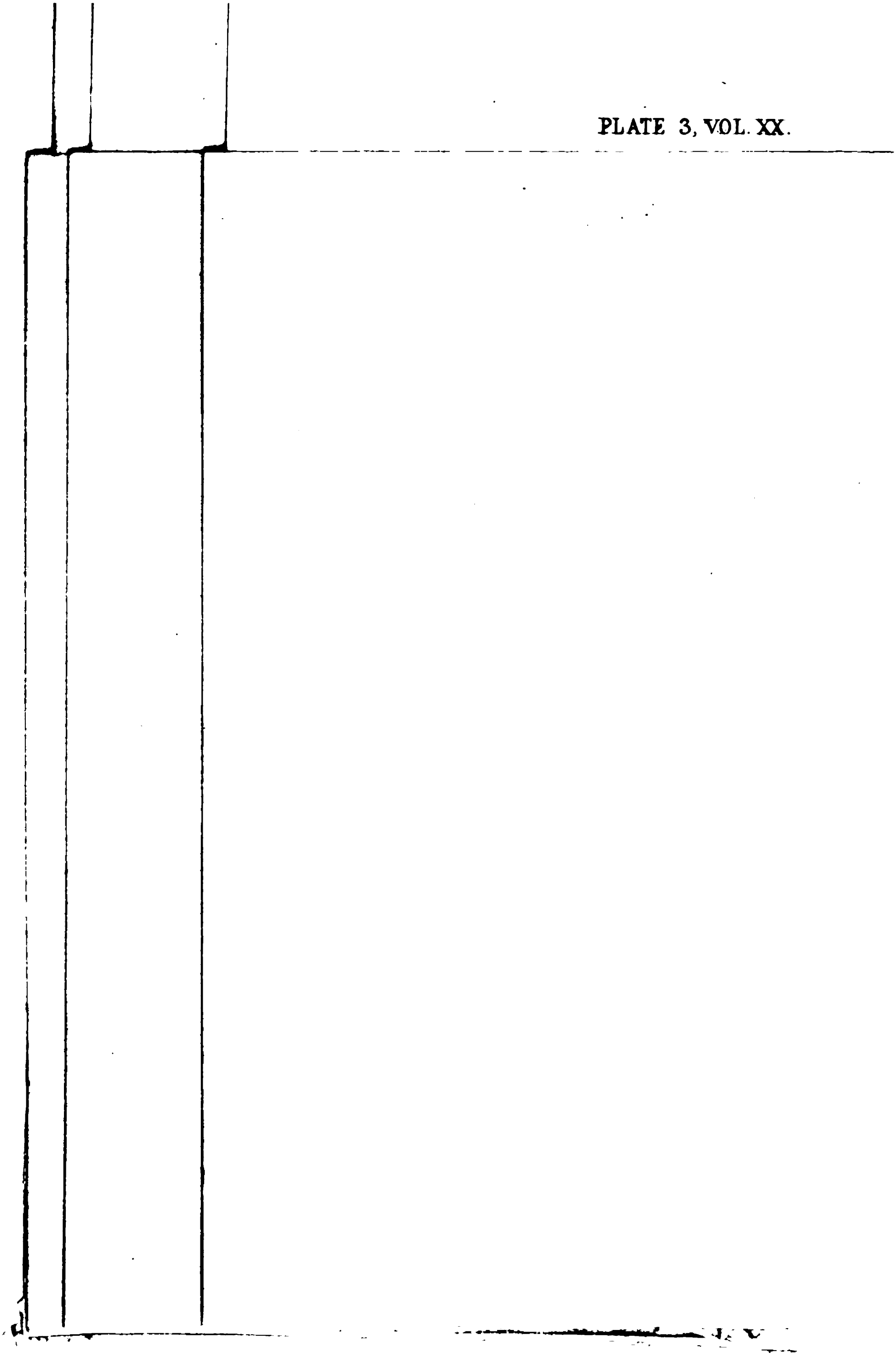


PLATE 3A VOL.XX.

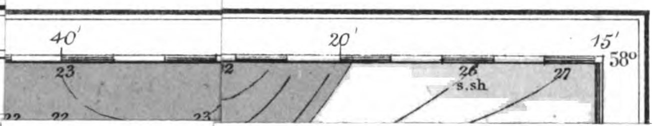

40'
20'
15'
58°
23
2
26
s.sh
27
22
22
23

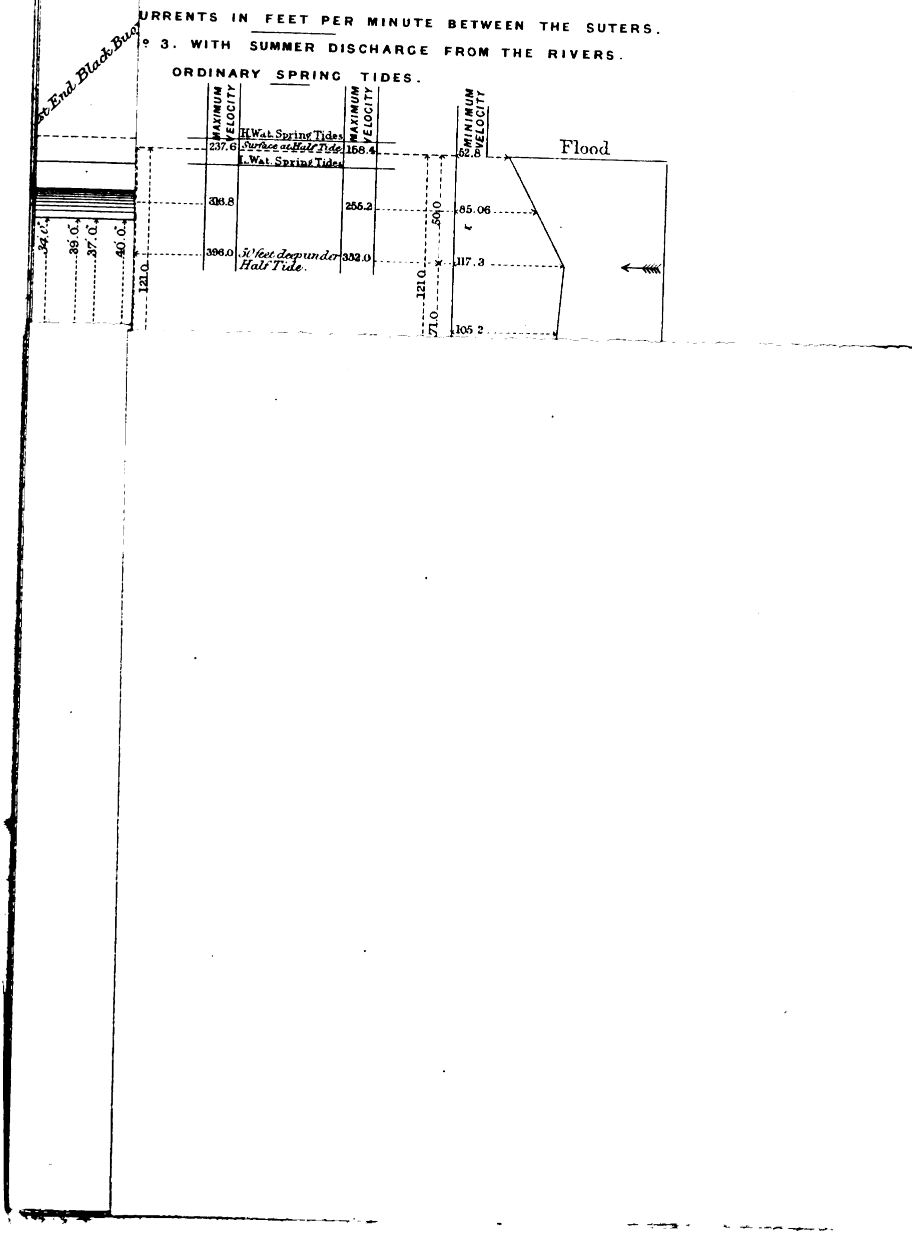
PLATE 3B VOL. XX.

ENT FRITH OF CROMARTY.

URRENTS IN FEET PER MINUTE BETWEEN THE SUTERS.

° 3. WITH SUMMER DISCHARGE FROM THE RIVERS.

ORDINARY SPRING TIDES.


st End Black Buoy
MAXIMUM VELOCITY
MAXIMUM VELOCITY
MINIMUM VELOCITY
H.Wat. Spring Tides
Surface at Half Tide
L.Wat. Spring Tides
237.6
158.4
52.8
Flood
316.8
255.2
85.06
396.0
50 feet deep under Half Tide.
352.0
117.3
105.2
34.0
39.0
37.0
40.0
121.0
50.0
121.0
71.0

Mr. Bidder,—President,—would preface the discussion by a few observations, in the hope, that they might widen the field of inquiry, which this valuable Paper had opened out. The North Sea was a subject of deep interest, whether viewed commercially, geographically, or physically. Commercially, because the amount of shipping and the value of the commerce upon that sea, were almost without a parallel. It was traversed by the numerous vessels engaged in the coasting trade of Great Britain, from the mineral districts of Durham and Northumberland, and it was the means of communication with the Baltic and with Germany, and with the north of Europe. Physically, it possessed features of remarkable interest. It extended from the shores of England to the low-lying coasts of Belgium and Holland; and further north, it received the waters of the Elbe, the approach to which, in the winter season and during the prevalence of north-west gales, would be almost impossible, were it not for the situation of Heligoland, which enabled vessels to take a fresh departure for the mouth of that river. The North Sea washed the Danish coast, and then approached the rocky coast of Sweden, which was protected by a series of low-lying islands, and which presented many difficulties in its navigation. It proceeded along the coast of Norway from the Christiania Fiord to the Naze, and from the Naze to the North Cape; but although the coast was rugged, the navigation was one of the safest in the world, for it was intersected with harbours of unusual extent, in which ships could quickly obtain refuge in all seasons, and during the most severe weather. On the British side, it washed the bold and rugged coast of Scotland, and of the north of England, and the low-lying coast of Lincolnshire and Norfolk. In this sea, the variation in the range of the tides was remarkable. From Dover to the Thames, it amounted to 18 feet, or 20 feet; on the coasts of Suffolk and Norfolk, it gradually diminished to 5 feet, or 6 feet; and further north, it again rose to 18 feet, or 20 feet. Then again, some singular phenomena presented themselves upon the Danish and Norwegian coasts. Currents were perpetually setting in eastward from the Holmen Light to the Skaw, varying in intensity according to the strength of the wind. The currents flowing into the Baltic, were also subject to wind influences. In connection with this part of the Baltic, he would mention an interesting fact, which he had never been able to explain satisfactorily. In the narrow channels, not more than 6 feet, or 7 feet deep, traversing the Danish Islands between Copenhagen and Kiel, the water was so fresh, that the steamers using it had no occasion to blow out their boilers, and he had even seen fresh-water fish in those channels. In traversing the fiords of Norway, the currents were also subservient to the wind, sometimes changing two, or three times in the course of the day, and their height varying from 6 feet to 9 feet, according to the direction from which it blew.

With regard to the theory of the Author respecting the Dogger Bank, it would be desirable to know the facts upon which it was founded; for without considerable currents, it could not increase to the extent predicted in the Paper, and it was not evident whence the material was to be derived, which could raise into an island, a bank equal in area to the principality of Wales. Having frequently crossed the North Sea, he had been, occasionally, becalmed upon the Dogger Bank, yet he had never been able to detect any current; indeed, the water was so quiet, that he was able to fish, which could only be done when the water was perfectly stagnant. Although in the North Sea the waves did not rise to any remarkable height, yet they were dangerous and treacherous; they were cross and abrupt, indicating that they were influenced by the bottom of the sea. A point particularly worthy of notice was the Jute Bank, facing the coast of Norway, where the depth suddenly increased from 40 fathoms, or 50 fathoms, to 190 fathoms, and even to 300 fathoms; upon the edge of that bank the seas were also of the same character.

Upon the British coast there were many important works, upon which it would be interesting to have the results of the experience of those who had been engaged upon them. He would mention, among others, the pier on the Tyne, and the reclamation of land upon the coast of Norfolk, similar works to which were now in progress in Holland, with a view of reclaiming land from the Schelde. There was, also, the great question of harbours of refuge.

Mr. JOHN MURRAY called attention to the charts of the North Sea exhibited, upon which he had inserted, against the chief localities (Plate 3), the time of high water at the full and change of the moon, and the ranges at spring tides; and also lines denoting the streams of flood, deduced from a consideration of the contours of the bottom. In the Paper he had slightly touched upon the subject of the winds of the North Sea, but it was sufficiently important to justify a more extended notice. With a gale in the Atlantic from the west, passing round to the north and north-east, a large mass of water was brought into this sea, producing a greater range of tide at high water along its coasts, which was felt at certain times through the Straits of Dover, as far as Dungeness and Beachy Head. With easterly and south-easterly winds, the flood tide was checked, and less water was brought into it. A westerly gale in the Atlantic, also, forced up the English Channel a large mass of water, which, passing through the Straits of Dover, affected the tidal range in the southern part of the North Sea as far as Yarmouth.

The southern part of this sea, in its connection with the estuary of the Thames, the Straits of Dover, and the upper end of the English Channel, was of such importance as to demand a separate Paper; he would, therefore, confine his remarks on that portion of the subject, to the Dutch coast. From the Schelde to the Texel, there were two high waters and two low waters; the one proceeding from the southerly current of flood in the North Sea, and the other from the northerly current of flood through the Straits of Dover. The first was called the proper high water, and was named by the Dutch the 'agger.' In consequence of the meeting of these tides, there was comparatively no rise, or fall, at the point A (Plate 3), as alluded to in the Paper. He believed, also, that there was no rise or fall of the tide in about 55° North latitude and 5½° East longitude, at the point B (Plate 3); but this had yet to be proved. This arose, in his opinion, from the different courses of the streams of flood; the one traversing in a southerly direction the east coast of England, ran directly from Flamborough Head south of the Dogger Bank to the mouth of the Elbe, throwing off a branch to the north-east, after passing the Outer Silver Pit. The Elbe branch was deflected to the north, and meeting with the stream of flood running southward parallel with the Danish coast to the east of the Dogger Bank, the two streams neutralised each other. On investigation, he was inclined to think, that there would exist two high waters and two low waters, on certain parts of the coast of Denmark.

In answer to a question from the President,—whether the tide was neutralised, upon the coast between Jutland and Norway,—Mr. Murray said, that the stream of flood from the Atlantic was absorbed in the deep water, parallel with the Norwegian coast, The tidal range at the Naze was scarcely perceptible, while in the shoal water at the Skaw, the tide rose about 12 inches. At the western entrance of the Agger Channel, the tidal range was from 15 to 18 inches; but in the shoal water at the Horn Point, it was increased to 5 feet 6 inches, and at Heligoland, from 9 to 10 feet.

Mr. J. T. **Harrison** said, that in considering this subject, a much more enlarged view of it should be taken. At an early period of the world, it was probable, that the North and the Baltic Seas constituted but one single sea, and that a spit now comprising a great part of Holland, Hanover, Holstein, and Denmark was formed within this sea, and so separated the Baltic from the North Sea. The materials of which this spit was composed were derived from the continued encroachments of the sea upon the east coast of England. By the Paper, encroachments were shown to be still going on at the present time, not only on the coast of England, but also on the coasts of Germany and Denmark.

In Mr. Harrison's Paper, read before the Institution in 1848,[1] he mentioned a spit which was formed at the mouth of the River Exe. This large sandbank, called the Warren, was then much reduced in extent. In the formation of spits of that kind, there appeared to be a gradual increase, so long as the quantity of materials which the sea had power to bring to that point, exceeded that carried past the estuary. But when the sea had washed away the adjoining coast to such a form, that the encroachment upon it was materially diminished, a period ensued when the quantity carried past, exceeded that brought by the waves washing along the coast to the spit, and instead of increasing, it thenceforth began to diminish. That period, so far as he was able to judge, had arrived, in the case under discussion.

There were some points connected with the tides and sandbanks, to which he would briefly draw attention. If he was right in his supposition, that a large part of Holland, Denmark, &c., formed a spit at the mouth of the Baltic, a considerable quantity of land along the coast of England must, at some time, or other, have been washed away to supply the materials for its formation. Instead, then, of agreeing with the Author's expectation, that the Dogger Bank would, eventually, form an island, he thought it far more probable, that the bank was originally an island, or that it formed, at one time, part of England. He had arrived at that conclusion from the following reasons. In the north of Scotland, the range of the Grampian Hills crossed the country from Islay to Aberdeen, and it was nearly parallel to the Dogger Bank. The granite forced from the interior of the earth in a molten state, was the cause of the upheaving of the several strata to the surface, and the hills formed of those strata maintained a direction parallel to the disturbing force. There was a peculiarity in the geology of England towards the south; the range of the Cotswold Hills, composed of oolite, diminished towards the Humber, but a little to the north of Flamborough Head the oolite again presented itself, so that the Humber appeared as though it had made a passage through the formation. It seemed probable, that whilst the Cotswold range of oolites and the parallel range of chalk, were due to the disturbing force in Wales, the chalk at Flamborough Head, and the oolites to the north of it, were brought to the surface by the eruption of the granite in Scotland. The cliffs at Flamborough Head, no doubt extended, at one time, into the sea; and in a line opposite to them, and parallel to the Grampian chain, lay the Dogger Bank. No reason had been assigned in the Paper, for the formation of a sand bank at that particular spot; but in regarding it as the remains of an encroachment by the sea, he could understand some of the other phenomena of the North Sea. The tidal wave, coming through the large opening between Scotland and Norway, and passing rapidly through the deep water, would be checked, and would form a standing wave at the Dogger Bank. Passing onwards, it would receive a second check at the White Bank, (the remains, probably, of the chalk range,) which would cause the formation of a third standing wave, and a deposition of sand such as that to be found on the coast of Holland, thus accounting for its remarkable parallelism to the Dogger Bank. The Paper did not appear to give any explanation of the peculiarity which the President had mentioned, that there was scarcely any tide at the mouth of the Baltic. Looking at the arc which the coast of England formed between Aberdeen and Flamborough Head, and considering that a wave raised up to 15 feet, or 16 feet would necessarily be reflected from it, and that this wave would be reflected, or rather, be generated at right angles to the coast, there would be a continuous accumulating wave towards the centre of the arc. Now, the centre of the arc formed by the British coast would be found to correspond with the southern coast of Norway; and, consequently, towards that coast a continuous wave might be expected to set from England. This was not a mere theory, for in Hobbs' "Sailing Directions" it was laid down, that "those, therefore, who sail from the westward, in order to make any part of the coast between the Texel and the Skaw, should look out for land in time; for it is very common in making it to find the distance from 20 to 30 miles less, than when sailing the contrary way in making the British coast."[1] He thought the absence of tide at the mouth of the Baltic was occasioned by the tides from the whole of the coast concentrating, hour by hour, at that point. The tidal wave, generated from the British coast, would carry the débris from the foreshore, and form a bank at some distance; there was such a bank, the Great Fisher Bank; the Little Fisher Bank, towards the coast of Jutland, being probably formed, in consequence of a standing wave motion of the water. The heaping up of the tides at the mouth of the Baltic, appeared to account for the constant stream which set in from the Baltic along the coast of Norway to the ocean, and it seemed to him, that all the sand and other materials carried from the coasts, were swept over the Jutland reef into this marine river, and carried by it into the ocean, its final resting place.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. vii., p. 327.

He would add a few observations on the meeting of the tides between Yarmouth and the Rhine, and the effects produced by it. About Yarmouth and Lowestoft, the spring tides rose only 6 feet, or 8 feet, whilst at a distance of about twenty-five miles on either side, at Foulness near Cromer, towards the north, they rose 14 feet, and at Orfordness, towards the south, 11 feet. There was excellent authority for stating, that at high tide the water was level along this coast, corresponding, probably, with that in mid-channel; at low tide the water at Yarmouth and Lowestoft must, consequently, be several feet higher than at Cromer and Orfordness. Now, as the level of the water in mid-channel opposite Yarmouth, was found by Captain Hewett not to vary, it did not require much proof, that towards low water, there would be a current from it to the adjoining coast, and that the current would become increasingly rapid at the same period, from Yarmouth and Lowestoft towards Cromer and Orfordness, the water, of course, making for that part of the sea the level of which was lowest at the time. To the north, the course would seem to be across those peculiar shoals, among which were the Ower and the Leman,[1] and to the south, across the sand banks at the mouth of the Thames. Now the currents which thus set across these banks, appeared to be the cause of their formation; the general shallowness of the sea, preventing the easy passage of the water, caused it to form a series of standing waves, and the moveable sand accumulated by the meeting of the tides, was deposited in the form of dangerous shoals at these standing waves, exactly in the same manner as, before its improvement, sand banks were formed at remarkably regular distances in the River Clyde. A somewhat similar series of shoals on the opposite coast, was formed on each side of the Maas Bank, and, probably, from the same cause, for there also the tides met. The "Sailing Directions" stated, that "it may easily be perceived whether you are to the northward or southward of the Maas; for, to the northward of the Maas, the stream of flood turns about with the sun, but to the southward, against the sun, till the last quarter-tide, and then it sets in towards the land."[1] The shoals in the positions referred to were, necessarily, modified by circumstances; but the point he was desirous of impressing was, that by a study of these circumstances, it was possible to explain the formation of every sand bank, properly so called.

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[1] *Vide* "Sailing Directions for the Navigation of the North Sea." Seventh Edition. By J. S. Hobbs. 8vo. London, 1846. Page 200.

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[1] Extract from Captain Hewett's Report on the Leman and the Ower Shoals, 1826. (See Hobbs' "Sailing Directions, &c.," pp. 34, 35.)

"As a summary, with respect to the tide, [at the Leman,] it may be observed, that the flood-stream springs up S.S.E. ¼ E., and terminates S.S.W. ¼ W.; that the ebb-stream springs up N.N.W. ¼ W., and terminates E.N.E.; that it is high and low water, when the respective streams are running in their full strength. . . It is also worthy of particular remark, that the stream of tide runs directly across the shoalest parts of the Leman, and at double the regular velocity; but it immediately resumes both the former direction and velocity. . . . ."

"The stream of tide runs over the shoal ridge of the Ower, as at the Leman, with an increased velocity, equal to nearly double its natural strength."

Again, in the directions for sailing among the shoals at the mouth of the Thames, (page 10,) it is said:—

"The ebb-tide sets obliquely, with much strength, over the Mouse and West Barrows; you must, therefore, be careful in going down, that it does not set you aground between them: indeed, it is necessary to use the same caution in passing through any of the channels, as the tides, setting W.S.W. and E.N.E., take an oblique direction over many of the sands and shoals, particularly those between the north end of Shipway and the Gunfleet."

Mr. J. SCOTT RUSSELL observed, that the Paper strongly recommended the study of the tides in the North Sea, as forming to a certain extent, a key to the local tides in the friths, rivers, and harbours, with which Engineers had to deal. It was also suggested, that a contour map should be made of the bottom of the sea, with the same care with which the Admiralty were now laying down the granite rocks of the coast of Scotland. So greatly had Mr. Scott Russell felt the necessity for such a map, that twenty years ago, when investigating the subject of the tides, he made a similar map, laying down contour lines of the bottom of the sea, at successive depths of 10 fathoms each. This discussion would have an important result, if it should be the means of inducing the authorities to direct the preparation of a contour chart of the sea, within the depth of 70 fathoms, or 100 fathoms, all round the British Isles.

He then directed attention to the tidal diagrams exhibited by him, and remarked, that they were maps of a series of tides as actually observed, showing a remarkable series of phenomena in the North Sea, and also in the Frith of Forth, which could not be accounted for, until these observations were made. In some parts of that frith there were, as also at some parts of the coast of Holland, four tides in twenty-four hours, a phenomenon which was, at that time, attributed to local disturbances only. In the year 1838, he stationed one of his assistants, at Stirling, with an ordinary tide staff, with orders that men should be employed to mark down, at intervals of five minutes, night and day, the exact height of the tide. The curves now exhibited were the result of those observations. The few, however, which were made the first year, appeared to be so anomalous, that they were repeated during the next year, at a greater number of stations, extending along the entire coast of the Frith of Forth. He failed also, then, in discovering the laws and cause of the phenomenon, and this he attributed to not having thought it necessary to take continuous observations, during the whole of the twenty-four hours. In the third year, the observations were made continuously, night and day, at all the stations during three months, under the direction of a Committee of the British Association,[2] until, at last, they were sufficiently multiplied, to enable the whole to be reconciled. At Stirling, there were four high waters, but the low water was entirely similar to that in other rivers. Whilst at Alloa, lower down the Frith of Forth, there were two low waters in each tide, as well as two high waters, or four of both, during every twenty-four hours, and these, or symptoms of them, were visible all the way down to the sea.

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[1] *Vide* "Sailing Directions, &c." By J. S. Hobbs. Page 160.

[2] *Vide* "Report of the Thirteenth Meeting of the British Association for the

The solution which presented itself to his mind was, that these anomalies arose from the two tides which entered the North Sea from its opposite, or north and south entrances; one effect being due to the northern stream of flood, exactly described in the Paper, which reached Aberdeen about 12 o'clock, and the Frith of Forth about 2 o'clock, arriving in the Thames about 12 o'clock. The other effect, he believed to be due to the southern tide along the Dutch coast mixing with the former flood stream, and following the ordinary laws of the propagation of waves. As the tide travelled faster in deep than in shallow water, one-half of the tide proceeding northwards from the Channel, would lap round the coast of Holland, and the other half, round the eastern portion of the coast of England, and it was well known, that the times of high and low water varied considerably on the latter coast, as they should do, if formed of two waves; at one point, the tides became extremely small, by the high water of the one filling up the hollow, at low water of the other. In following the course of the tide to the Frith of Forth, it would be found to arrive there twelve hours later than this tide from the north, and it would enter it two hours sooner than the next following tide would reach it from Aberdeen. He was thus led to the conclusion, that the early tide was the irregular, or the Dover tide, and that the later tide was the regular, or the Aberdeen tide. The trend of the coast was, naturally, such, that if there was a tide wave of this kind, entering the North Sea from the English Channel, and running out into the deep water, it would be caught in the nook, or hollow angle, at the mouth of the frith, which was at the apex of a great indentation on the coast.

Now it would appear, at first sight, almost impossible to prove this theory: he, therefore, placed great weight upon the observations which enabled him to do so, because they showed, that sometimes, by taking a large view of a subject, difficulties might be explained, whilst a narrow view would either afford no explanation, or would lead into absolute error.

The diurnal inequality in the height of the tides, was generally known; but the diurnal inequality in the time of tides, although it

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Advancement of Science; held at Cork in August 1843." 8vo. London, 1844. Page 110. Also, "Report of the Fourteenth ditto; held at York in September 1844." 8vo. London, 1845. Transactions of the Sections, page 6.

had been deduced theoretically, had not been previously ascertained by actual observation, because it was difficult to detail the precise times of high water. Now these two anomalous tides showed, in the strongest manner, how it was possible to tell the age of the tides, by means of the diurnal inequalities; because, if a tide entering the North Sea from the southward, was of the same age as another entering from the northward, they would be, both of them, greater in the morning and smaller in the evening, and they would also, both of them, be earlier in the morning and later in the evening. But if they were at different dates, at intervals of twelve hours, then one must be a morning tide and the other an evening tide, and the one would be larger whilst the other was smaller, and each pair of tides would thus consist of a smaller and a larger tide, and of an earlier, and a later tide. Such was exactly the fact, as observed. On calculating the heights and times of these two tides separately, in the ordinary way as separate tides of 12 hours 24 minutes difference in age, he had found the observed differences in the diurnal inequality of the height and time of these two anomalous tides, to tally exactly with the calculation. The cause of the diurnal inequality was the moon's declination, and these anomalous high waters varied exactly after the measure of that declination, both in height and time, but in pairs of opposites. He had thus been able to construct as exact tide tables for the prediction of these anomalous tides, as for the most regular and ordinary tides of the sea. Curiously enough, he had found, that the morning tide on the north side was, generally, the higher tide, and on the south side, the lower tide and vice versâ, on the same day, showing that this Aberdeen tide came in and made high water on one side of the frith, and the other tide came in and made high water on the other side of the frith; and that the one was + inequality and the other was – inequality, as it ought to be, if one tide was twelve hours older than the other.

The whole subject was one of great interest. He had further carried out observations on the River Tay, and he might add, that on the eastern coast of Scotland, the symptoms of this southern tide, were, generally apparent, whenever they were carefully sought for. He was convinced, that the tides really traversed the British seas as if they were great waves of translation, and he had mapped out the whole of the northern coast with lines, taking as his guide, the depths of the water, and that depth gave the velocity of the transmission tides, in the following manner. At the depth of

1 fathom, the tide wave travelled 8 miles per hour.
10 fathoms ,, ,, 25 ,, ,,
20 ,, ,, ,, 35 ,, ,,
50 ,, ,, ,, 57 ,, ,,
100 ,, ,, ,, 80 ,, ,,

By following the indications given, and calculating the velocity in opposite directions, he found that the northern and southern tide waves met each other in the region where there was no tide. On certain days there was no tide over a very large extent of the North Sea, because there was a large area, when the times of tide were such, that the high water of the one, filled up the low water of the other. The separate waves of high water travelling along the coast, could not be directly followed by observation, because these two, travelling by different directions, and at different angles, made a third wave, the height of which was different from the natural height of either high water. For a full explanation of all the phenomena of tides in the North Sea, it was absolutely necessary to construct a good map of the contour lines, and to thoroughly trace out the different velocities of the waves, according to the depth.

Not satisfied with this speculative opinion upon the mode of propagation of the tides, he caused the bottom of a reservoir to be modelled, so as to form as correct a representation of the bottom of the North Sea, and of all the coasts of Great Britain, as could be obtained from the best charts and maps. He then produced a great wave of translation in the deep water, representing truly the tide wave, and he found that it entered the North Sea at opposite ends, thus exhibiting in miniature, the actual phenomena of the distribution and combination of the tidal waves round the coasts of England, Scotland, Ireland, and Holland.

Mr. BIDDER,—President,—remarked, that it would complete Mr. Russell's observations, if he added an explanation of the propagation of the tidal wave, through the Straits of Dover into the North Sea. The velocity of the wave, whatever relation it bore to the depth, had also relation to the height of the water it traversed.

Mr. J. SCOTT RUSSELL said, that the channel in that part of the North Sea was generally deeper in the middle, and shallower at the sides. Now the tide wave travelled faster in deep than in shallow water. Consequently, on emerging from the Straits of Dover, the tidal wave would, in a short time, form a convex line, trending towards, as well as along the shallow shore, and moving in towards the land, instead of continuing along it at right angles. This wave became smaller in the deep water, because its direction was altered, and it hugged the coast; whereas in the shallow water, it was larger, because it performed a motion, partly of progression, and partly of rotation. This was a phenomenon universally observed, in the propagation of waves of the first order. In the Dee and in the Solway Frith, the tide advanced much more rapidly in deep water, than over the sands. The height of the wave was an element in the velocity, because it must be added to the depth of the water in calculating the velocity according to the Table, already alluded to. If, for example, the height of the tide was 20 feet, and the depth of the sea, at low water, was 60 feet, the wave would have the velocity due to 80 feet, instead of the velocity due to 60 feet of depth. This principle explained the cause of the high tide-waves, far up a shallow river; because in the shallow water, the height of the tide-wave bore a very large proportion to the depth of the water, and thus the highest part of the tide-wave moved with a much greater velocity than the lower portions. The bottom of the wave would, perhaps, be moving with a velocity due to a depth of only 30 feet, the middle of the wave, with a velocity due to a depth of 50 feet, while the top would be moving with a velocity due to a depth of 70 feet. The tide-wave was thus distorted and dislocated, in travelling along shallow water; the top of the wave, at last, over-running the bottom, formed the breaking wave, or bore of the tide: such as was observed in the Solway, the Dee, and other similar cases.

Mr. W. A. **Brooks** was unable to understand how the wave could get so far north, beyond the Straits of Dover. He thought, that the phenomena in the Frith of Forth might be more easily accounted for, by the supposition of two high waters, one produced by a tidal current along the shore, and the other coming in later, from an offing current.

Mr. A. **Giles** said, that high water had been stated to take place at Dover at 10 o'clock and at Aberdeen at 12 o'clock, and that the tidal wave passed from Dover to the Frith of Forth. Now he thought, that if an Engineer wished to design a wave trap, he would make just such an outline of coast as that presented by the North Sea after passing the Straits of Dover. The wave passing through the Straits, would expend itself over the wide area between the coast of Holland and Lynn Deeps, and then fall to a perfect level, so that the wave would cease to exist. There was another difficulty in the theory of the tidal wave passing from Dover to the Frith of Forth, which was, that to arrive at the latter point, the tidal wave must cross low water. He thought the phenomena observed in the Frith of Forth were, probably, due to the first tide flowing past the north of Scotland, and the second tide flowing north of the Shetland Isles.

With regard to the formation of the Dogger Bank, he could not understand the theory, that the tide, on striking it, became stagnant water, and was then translated beyond the bank. If the currents shown on the chart were correctly represented, there must be an eddy, which would be sufficient to account for the formation of the bank. He had been engaged in works at Copenhagen, and he could certify, that the water at that part of the Baltic, was not salt, and that although there were no tides, the level of the water was often influenced by the wind to the extent of 3 feet, or 4 feet in height.

Mr. J. Scott Russell observed, with regard to the explanation just suggested, of the phenomena in the Frith of Forth, that both tides would, in that case, increase, or diminish at the same time, which was contrary to fact.

Captain Burstal, R.N., remarked, that the subject could not be thoroughly investigated, without a correct map, but, unfortunately, the Admiralty surveys had not extended sufficiently far north, to enable contour lines to be correctly drawn over the whole area of the North Sea; the soundings had been taken with sufficient minuteness only from Flamborough Head southwards. With respect to the Dogger Bank, the fishermen who were constantly trawling at that spot, reported, that there was a regular north and south stream running over the bank, at the rate of from 2 miles to 3 miles an hour. If that was the case, it was unreasonable to suppose, that any great deposit could take place, or that the bank could be other than a natural formation. As the flood wave which filled the North Sea, came from the Shetland Islands and the north-west, the existence of such a stream might be naturally inferred. There was also a strong stream in the deep water of the Sleeve, between the coasts of Norway and Jutland running to the eastward. Near the south part of the coast of Norway, the direction of the stream was westward, and it appeared to be an eddy. It was reasonable to suppose, that the rivers, at their mouths, took the same direction as the stream; and at that point, the tide seemed to be expended, in the same manner as it expended itself at some point between Cromer and the Elbe, where Captain Hewett was not able to detect any rise, or fall. That the wave of translation was forced down from the North Sea, and occupied the southern part of the coast of England, there could be no doubt from this fact, that whenever the wind was from the north-west, there were, invariably, high tides on the eastern coast of England. When the wind was from the south, there were low tides. Near the Straits of Dover the tide flowed about a quarter to 11, and it would, probably, expend itself, and gradually arrive at the mean sea-level, so that on the coast of Cromer and Yarmouth, there was only a flow of 5 feet, or 6 feet.

One of the most curious banks with which he was acquainted, was the Varne and Ridge, the surface of which was covered with shells. The stream ran at an angle of about 25° with the line of direction of these shoals. The fact, that a north-west wind produced the highest tides, was sufficient evidence to show, that the principal tide-wave was supplied from the north, and not from the south.

In answer to questions from the President, Captain Burstal said, he thought there were no authoritative observations which indicated any permanent rise at the bottom, or in the banks of the North Sea. Captain Hewett had carried on his experiments during a great length of time. He moored a vessel, head and stern, in the middle of the North Sea, and he kept a boat continually drifting, during the whole portion of the twelve hours, for several successive days together. This was repeated twenty, or thirty times, without detecting a range of tide of more than 2 feet, or 3 feet.

Mr. A. Giles explained, that his objection to the theory of the propagation of the wave from Dover to the Frith of Forth was, that it must, necessarily, cross low water; for while it was high water at Dover and at the Frith of Forth, it was, at the same time, low water near Lynn Deeps. From that point, therefore, the wave, if translated, would be compelled, in its passage to the Frith of Forth, to travel up-hill.

Mr. J. Cockburn Curtis thought the Institution was under very great obligations to the Author, for the able manner in which he had collected and grouped together, the information contained in the Paper. The first step in all scientific inquiry was, undoubtedly, the careful collection, and the analysis and classification of existing facts. But the amount of information respecting the North Sea was, at present, insufficient for the formation of any correct theory, as regarded its hydro-geological history, or the laws of the development and course of the tidal wave, within its limits.

Mr. Curtis had paid considerable attention to the subject of the best and clearest mode of drawing up charts for different purposes, but he could not agree with the Author, that the charts as now published by the best authorities, were little else than a mass of figures, which, even after attentive study, could not be long retained in the memory. It must be remembered, that, hitherto, charts had been principally published for the exclusive use of the mariner in navigating his vessel, and that for this purpose a somewhat conventional, or arbitrary system was necessarily adopted, in order to condense the information. It was, therefore, rather unreasonable to complain, that charts so prepared were not readily available for the minute and abstruse, although useful, investigations of the scientific man. Some years ago, when employed in the Hydrographic Office of the Admiralty, he was engaged by the late Mr. Bate, the then Admiralty Chart agent, with the sanction of the late Sir Francis Beaufort, to investigate the best mode of extending the sale of the Admiralty Charts in the merchant service; and he had than an opportunity of hearing the opinions of a number of practical men on this subject. Charts, or nautical plans, might be considered as required for three different purposes; scientific, strictly nautical, and warlike, or military purposes. Now, the facts required to be recorded, and the mode of classification necessary to condense the leading points of information, were so diverse in character in each case, as to render it a task of extreme difficulty, to make one document serve for all three purposes. For scientific objects, he believed the contour-shaded chart was best compiled with the different degrees of depth, and not indicated by varied colours, but by different shades of the same colour. Blue, he preferred, as being the most natural colour for water, the deeper water being shown by the deeper shade of colour, so that the deepest water on the chart became what the sailors literally called it, 'blue water.' So early as 1842, he had advocated this system as a valuable aid to tidal and hydraulic investigation, and when Mr. Wheeler Jackson's Paper was discussed at the Institution, in 1847, he exhibited several charts of Cork Harbour and other places,[1] contour-shaded in the mode he had indicated, and some of those he again submitted on the present occasion. Though not agreeing with the Author, upon the question of the employment of varied colours for contour-shading in hydraulic investigations, he still thought, that much good would be done by the discussion, in directing the attention of the Government and of scientific authorities, to the necessity which existed for maps of such a character; and he would further suggest, that as the Ordnance Maps had already the contour lines drawn at different depths along the coast, the sea might, in addition, be contour-shaded. As the different sheets had also the advantage of being all on the same scale, a complete hydrographicmap of any portion of the coast, could then be obtained at a moderate expense, for the purpose of scientific, or hydraulic investigation. But such a system of contour-shading, he considered inapplicable to strictly nautical charts, drawn up for navigation purposes, for it was important to the sailor to have as much white paper as possible, to enable him clearly to see the intersecting pencil lines, by which he marked off the position of his vessel. It must be remembered, that in nearing the land at night, the place of the vessel had frequently to be laid off by the mariner, under the most disadvantageous circumstances, as for instance, by the dim light of a deck lantern, and with his eyes bleared with wind and salt water, and strained with looking out in a gale. In the nautical chart, the reverse system to that which he advocated for general scientific purposes was, therefore, required; the land, the shoal portions, and the dangers should be made dark, while the fair-way channel should be made as light as possible. Under-water banks should, to use the expression of sailors, be 'well-sausaged up,' by black-dotting their margins; the lights, floating and fixed, should be distinctly and strongly coloured in red and yellow; and every assistance towards marking off the vessel's position and her future course, such as scales, compasses, leading marks, &c., should be freely, but not unnecessarily, distributed over the face of the plan.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. vi., p. 128.

In charts for warlike purposes, where the smallest scrap of information given by the surveyor might, incidentally, be of vital importance to the success of any military, or naval operation, he thought that fac-similes of the surveyor's own drawings, were the most useful. Although he freely acknowledged, that on many points, there was much room for improvement, yet he believed, that on the whole, the British Admiralty Surveyors, the Hydrographic Office, and the chart publishers, had produced charts which, for their accuracy and practical utility in time of peace, or of war, were unsurpassed by those of any other nation in the world.

Amongst the contour-shaded charts which Mr. Curtis had submitted to the Institution in 1847, was one of the British Isles, in compiling which, his object had been to endeavour to trace the line of the deepest water, and hence, the probable course of the tidal wave. But from the limited information then in existence, he could only attain a very doubtful and rough approximation. On the present occasion, he had re-examined the data in reference to the North Sea, and he found, that since that period, little had been added of any service towards determining the line of deepest water.

The Admiralty Charts of the North Sea were, at present, divided into three sheets. On the northern sheet, (Sheet III.,) extending from the parallel of the Frith of Murray to that of Flamborough Head, he found the following note:—"The soundings upright, in hair lines, are from doubtful authority." On examining the sheet, it would be seen, that except in the immediate vicinity of the shores on either side of the North Sea, the soundings were very sparingly distributed over the face of the sheet, and that those in the middle of the sheet, which were the most important in accurately tracing the contour lines of the bottom of the North Sea, were nearly all in the character described to be of 'doubtful authority.' The same remarks applied to the northern and eastern portion of Sheet II., which extended from the parallel of Flamborough Head, to that of Orfordness. Sheet I., from the parallel of Orfordness to that of the Straits of Dover, and the southern portion of Sheet II., which delineated the valuable surveys of Captains Hewett and Washington, R.N., and the portions of Sheet III., in the immediate vicinity of the shore, were, in point of fact, the only parts of the North Sea upon which contour lines could be accurately laid down, or the deepest channel be traced out.

The tidal question also presented similar difficulties; the observations being chiefly confined to those of the time of high water and the rise and fall of the tide, at different stations along the shores of the North Sea, and to the changes in the direction of the currents which, in the open sea, were of more consequence to seamen than the time of high water, or the rise and fall of the tide. The only observations of the time of high water, and of the rise and fall of the tide in the deeper part of the North Sea, were those made by Captain Hewett, in 1840, at the spot commonly called 'Professor Whewell's Node,' in lat. 52° 27½' N. and long. 3° 14½' E., and the corroborative observations made in 1849, by Captain Washington, (Assoc. Inst. C.E.,) about 12 miles to the southward of that spot. A reference to the reports of those officers published in the "Nautical Magazine," would also show the difficulty and expense of making such observations. The time of high water was the main element for tracing co-tidal lines. This time, except as deduced from the time at which the flood and ebb streams turned, could not be obtained for tracing co-tidal lines in the middle of the North Sea. The many vitiating causes, arising from the simultaneous tide observations along the shore being comparatively few in number, and frequently made at stations within the mouths of rivers, or at parts of the coast with outlying banks, or where the time and height of high water were otherwise affected by the configuration of the shore, prevented any deductions beyond an approximation, towards determining the littoral extremities of the co-tidal lines. Under these circumstances he considered, that the Author, in describing the tidal phenomena of the North Sea, had exercised a wise discretion, in confining himself to a statement of the direction of the tidal stream as recognised by seamen, instead of attempting to theorise upon the details of the progress of the tidal waves, as assumed to be developed by co-tidal lines.

He was inclined to think, that Mr. Scott Russell was misled in his deductions, when tracing the passage of the southern branch of the tidal wave, through the Straits of Dover, to the east coast of Scotland. Although he was quite prepared to admit, that tidal waves did cross each other, yet the broad facts, that the southern branch of the tidal wave entered through the Straits of Dover, (a channel, at the most, only 25 miles wide, and 28 fathoms deep,) and that the northern branch which came round the north of Scotland, entered the North Sea by a channel of more than 200 miles in width, and of an average depth, at the least, of 80 fathoms, conclusively showed the comparative volume of the tidal wave in each case. It must also be remembered, that after passing the Straits of Dover, the southern tide-wave, from the greater width of the channel, underwent a progress of degradation, which must, eventually, annihilate it. Under these circumstances, and taking also into consideration the absence of any exact information as to the configuration of a large portion of the bottom of the North Sea, he contended there were no grounds for supposing, that such an extraordinary phenomenon existed, as that which had been assumed by Mr. Scott Russell.

There were many other peculiarly interesting points in the Paper, to which time would not permit him to allude, but which were deserving of the particular attention of every student of hydraulic science. In conclusion, he expressed the gratification he had derived, not only from the valuable information afforded in the present Paper, but also in the others, with which, from time to time, its Author had enriched the Transactions of the Institution.

Mr. Ralph Ward Jackson hoped, that the discussion would not be limited to the tides of the North Sea, but that it would embrace the harbours and other works more particularly within the scope of Civil Engineering. After a full consideration of the position and phenomena connected with the Dogger Bank, he had arrived at the conclusion, that it constituted what might be termed the 'Bar of the North Sea.' It was necessary to assume some point for the commencement of the tides. Assuming, then, that the Irish Channel, the English and Bristol Channels, and the North Sea all became filled at the same time, he believed that Mr. Scott Russell had rightly described the great tidal stream as coming from the south-west, and striking against the south-west parts of Ireland at Cape Clear. It was the great Pacific tide, coming from the southward and the Atlantic, or Western Ocean, which fell upon the shores of the British Isles, and not that from the north-west. The direction of that great ocean wave was from the southward and westward, and it entered the North Sea, round the north of Scotland and the Orkney Isles, being first divided by the western side of Ireland, thence falling on the western coast of Scotland and the Hebrides, and so travelling to the north-east, and rounding into the North Sea between the Orkneys and Norway. Supposing such to be the course of the great ocean wave, or ocean stream, which was to fall into the North Sea, and that it first struck against the south-west coast of Ireland, it would there naturally split into two parts, one taking a northerly direction, and the other rounding to the south, at Cape Clear. The southern tide thus entered the Irish, the Bristol, and the English Channels. In the English Channel it, at first, entered a space of about 100 miles, between Land's End and Ushant. It was then checked in its progress, between Portland and Cape La Hogue, where the width of the Channel was reduced to about 58 miles, and afterwards between the South Foreland and Cape

Grisnez, where the width was reduced to 20 miles. The Atlantic was thus pressed into the English Channel, and being hemmed in at the Straits of Dover, naturally occasioned the great rise of tide, which was there observed. He considered, that the Straits of Dover might be regarded as the safety-valve of the North Sea, without which, it was his impression, that the southern part of that sea would gradually fill up. The same effect was produced in the Bristol Channel, where the great breadth and volume of water which entered it, not having sufficient space by which to escape, caused the extraordinary rise of tide in that channel. The northerly tide, after passing to the north-west of Ireland, fell towards the north-east upon the Hebrides, and thence to the Orkneys, from which it rounded into the North Sea; the width between the Orkneys and the coast of Norway, being about 400 miles. It was, therefore, inconceivable to him, that the great sea, or northern tide stream, with a width of 400 miles at its point of entrance to the North Sea, could be overcome by such a comparatively small stream as that passing through the English Channel at the Straits of Dover, where the width was only about 20 miles. He thought that consideration a sufficient argument against the theory, that the flood tide of the North Sea was from the southward and passed through the English Channel.

With regard to the Irish Channel, Mr. Scott Russell had correctly shown on his map, the flood tide entering from the south as well as the north, and the two tides meeting somewhere about Dundrum Bay. The distance between Carnsore Point, (the south-east point of Ireland,) and St. David's Head, near Milford Haven, was about 45 miles. There was thus a space of 45 miles in width, for the great Atlantic tide to enter the Irish Channel from the south; but the width for the tide entering that channel from the north, between Fair Head, (the north-east point of Ireland,) and the Mull of Cantyre was only 13 miles. The consequence was, that the southern tide travelled about 130 miles and the northern tide only 60 miles, to their point of meeting, near Dundrum Bay, whilst the southern tide also supplied the whole of the Irish Channel south and east of the Isle of Man, besides the Rivers Dee, Mersey, and Ribble. If such was the case, it was impossible, that the North Sea could be fed by the southerly tide from the Atlantic, after entering the English Channel, a width of only 100 miles, and then running up it for about 290 miles to the Straits of Dover, where the width was reduced to about 20 miles, when there was a northerly tide entering it at a width of 400 miles, with no greater contraction than 170 miles at the narrowest point, between Yarmouth and the Texel.

The best authority on the tides of the English Channel, was that of the late Admiral Beechey. The Paper by that officer, with twelve maps, published in 1851,[1] described so minutely the manner in which the tide occupied the twenty-four hours, that Mr. Jackson had compiled from it some diagrams, which he exhibited at the Meeting. The observations of Admiral Beechey exactly corresponded with the sailing directions, in accordance with which mariners navigated their ships. In discussing this subject, it would be necessary to take a tide of twelve hours,—six hours of flow and six hours of ebb,—and to assume, that it was calm weather. Admiral Beechey had divided the tides into establishments; and he had found, that the tides between the Start Point and Lynn Deeps was one establishment. The flood tide came round the Orkneys and Duncansby Head, passed Kinnaird Head, and thence ran along the east coasts of Scotland and England, and was met by the southern ebb tide off Lynn Deeps. The flood tide then curved round to the southward of the Dogger Bank, crossed the Texel, passed on to Heligoland into the Elbe, then deflected into the Sleeve, stopped from entering the Kattegat at the Skaw, finally turning round in the Sleeve towards Christiania, and thence round the Naze of Norway. The flood tide, at that point, then proceeded towards the north, having, in fact, nearly described a circle. Though to a much smaller extent, he had found a similar effect and direction of tidal water in Hartlepool Bay, to that in the North Sea.

The object of Engineers should be to study the laws of nature, and to apply to them the resources of art. He believed the Dogger Bank to have been formed in the same manner as bars of rivers, that it was the result of the conflict between two opposite tides, or streams. It was a fact, established both by Admiral Beechey's publication and by the practical knowledge of mariners, that the tides of the North Sea really did meet about Lynn Deeps; the ebb tides running northwards from Dungeness, meeting the flood tides from the opposite direction; and, consequently, for ages past, accumulations had been going on at the head of the North Sea. The outfalls on the ebb tides from the Thames, from the whole of the Dutch coast, from Lynn, from the Humber, the Elbe, and other rivers to the south of Lynn Deeps, had been going on for centuries, and not being able to get further north, in consequence of the flood tides from the north meeting the ebbs from the south, at the point off Lynn Deeps, deposits had naturally formed, and might be expected to continue. It was impossible to say how long the North Sea south of the Dogger Bank, had been in its present condition; but there was now double the depth of water on the north side of the Dogger Bank, than there was on the south side. That was an additional reason, why comparatively shoal water passing through the narrow Straits of Dover, over the southern portion of the North Sea, could not make its way, as flood tide, to the Frith of Forth, as had been suggested. When the flood tide had cleared its way from the north to Dungeness, and the western tide up the Channel to about the same point, (where, in fact, the two tides met,) the tide was considerably ebbing to the west, at the Start Point, and to the north, at Lynn Deeps. This peculiar tidal establishment between these two extreme points was 360 miles, with its middle, or meeting point, about Dover and Dungeness, giving about 180 miles to each tide. At Lynn Deeps it was high water about 6 o'clock, at one end of this tidal establishment, and at the Start Point at the other end, at about the same time, and six hours afterwards there would be low water at each place. There was thus an oscillation of a great tidal wave, or stream, between those two positions. When the North Sea and the English Channel were once full, they did not empty themselves again.

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[1] *Vide* Phil. Trans., 1851, page 703.

There were also, between other ascertainable points, regular oscillations, or tidal establishments. He believed another tidal establishment extended in the North Sea, between Lynn Deeps and abreast of the Murray Frith; it being about high water at the one point when about low water at the other, and vice versâ. Therefore, he again suggested the impossibility of the flood tide passing from the English Channel to the Frith of Forth, when at about the very time of its being high water off the Murray Frith, it was high water off Dover and Dungeness, whence the ebb tide set down the English Channel to the westward. With regard to the Frith of Forth, and St. Abb's Head, taking also the Murray Frith and Kinnaird Head, he found, that the tide, after coming round Duncansby Head, hung upon, or was affected by St. Abb's Head in the one case, and Kinnaird Head in the other; and that in both instances the tide then turned into each frith to the westward. It was, doubtless, that circumstance which had given rise to the notion of there being two tides in those friths. The same remark applied to Hartlepool Bay, to Lynn Deeps, to the Sleeve, to Cardigan Bay, and to other places where deflections were caused by headlands, or projections, opposing the direction of either flood, or ebb tides.

Mr. Ward Jackson, at the suggestion of the President, added some remarks relative to Harbours of Refuge. Taking a general view of the question, he thought that the points for harbours of refuge for saving life and ships, were precisely those where the greatest number of ships were generally lost,—where ships were caught in heavy seas and gales, and could not clear the land on either tack, starboard, or port,—and in deep bights of the coast. To place them on prominent points would not be attended with much advantage to vessels in danger, and were not to his mind the right places, although for strategical purposes, in times of war, projecting points of the coast might answer best. The points he should advocate, were Hartlepool Bay and Filey Bay. Upon the north-east coast there were, frequently, from five hundred to seven hundred ships at sea, yet on the whole coast, there was not a single place for refuge at all times of tide. Filey Bay would be an excellent place to which, in south-east gales, loaded ships might run for protection. When gales from that quarter overtook vessels which had already arrived near Flamborough Head, the masters were loth to run back again to the northern loading ports, and, therefore, a place of refuge was wanted for such loaded ships. But for such protection in Filey Bay, the work should not be on Filey Brig Rocks, but on the opposite side of the bay, towards Speeton Cliffs. Hartlepool Bay was another suitable position for a harbour of refuge; and it would also be desirable to make others further north, where there were requirements for harbours. He thought, that this great maritime country should support the Government, in expending any amount of money, which might be required for these important purposes.

Mr. W. A. Brooks remarked, that in many places there were two tides; at Portsmouth, and at the adjacent ports, for example. The earliest tide came between the Isle of Wight and the coast of Hampshire, and the later tide came round the back of the Island. The remarks of Mr. Scott Russell were correct, as regarded the tides in the Irish Channel, and a proof of their truth was the great accumulation of tide in the vicinity of Liverpool, where the two tides met, and where there was, consequently, a rise of tide of 33 feet. But there were no facts, according to Mr. Brooks's observation of that part of the coast, to warrant the statement, that there were two high waters on the north-east coast, even so far as Lynn Deeps. With regard to the phenomena in the Frith of Forth, he had arrived at the conclusion, that they were, probably, the result of the casual augmentation of the body of water, by the sudden discharge of freshes, from time to time, rather than that of any fixed natural laws producing two tidal waves; inasmuch as in many of the tides recorded, there was not the slightest trace of two high waters. In the upper and narrower portions of the tidal navigation of the Tyne, he had observed similar phenonena to those described as having taken place at Stirling; the discharge of the land water had a marked effect, which occurred, sometimes at high water, and sometimes at low water. In the Paper the Frith of Dornoch was represented as having a bad bar; but that was scarcely correct, for, at low water, there was a depth over it of 11 feet, which was about the average depth of the river. It was also stated, that the water line at that place had little, or no slope; and therefore, contradicted a certain theory as to the cause of the existence of bars. He doubted whether there were sufficient data to establish that fact. Sometimes, the Tyne and the Wear showed very little slope at low water, but if the observations were taken with a fair ordinary ebb, a very great slope was then found; and judging from the soundings and from the form of the Frith of Dornoch, he thought extended tidal observations would, probably, show in that channel also, a decided slope at the time of low water. The Author had contrasted the flow of the tide in the Tyne and the Wear, with that at Hartlepool; and it was the general opinion, that the rise of tide at the mouth of the Tyne was only about 14 feet 6 inches. This impression was owing to the observations having been taken at the wrong place; at Shields, instead of on the bar, at Tynemouth, outside of which, the rise, in ordinary spring tides, exceeded 16 feet. Many tidal results were deduced from coast-guard observations taken at improper places, and which did not give the true sea flow. At Shields Harbour, the tide was frequently prevented, by easterly winds, from ebbing to the ordinary low water at sea, although there might be, at the same time, a good clear ebb further up the river; thus making the seaward reaches of the river appear to have little fall at low water, whilst with a true ebb at sea, a considerable fall would be found to exist.

Captain W. S. Moorsom remarked, that the double tides alluded to, as occurring at Portsmouth, extended along the Dorsetshire coast, and they would also, probably, be found to take place at other portions of the coast of England; but he thought they might all be fairly attributed to local, rather than to any great oceanic causes. One great force which, no doubt, exercised a very powerful influence in the North Sea, had not as yet been referred to; he alluded to the returning currents of the great Gulf Stream. It was well known, that West Indian weeds were continually thrown by that stream, upon the northern and western coasts of England, and the fact of that current taking a southerly direction, rather tended to destroy the theory which Mr. Scott Russell had so ably propounded, inasmuch as it was fair to presume, that it would have the effect, in some degree, of annihilating the wave which found its way northward, in and from the Straits of Dover. This force would act in addition to affect the wave, already diminished by its being throttled, as it were, in the Straits. He hoped, that the discussion upon this important Paper would have for result, the collection of local facts, which would enable Engineers to arrive at correct conclusions upon these tidal phenomena, and upon their right application to the purposes of engineering construction.

Mr. Redman observed, that there was some confusion of ideas, during the discussion, relative to the main tide from the westward, as to whether it consisted of one complete wave, or two waves. The tidal wave struck Cape Ortegal, the north point of Spain,—Ushant, the north-west extremity of France,—the Scilly Islands, the south-west of England,—and the Mizen Head, the south-west extremity of Ireland, at about the same hour, viz., from 3 to 4 o'clock. It traversed the western seaboard of Ireland and Scotland in about eight hours, and also the English Channel, making high water at the mouth of the Thames in the same period of time. The wave from the south-east of Scotland to the mouth of the Thames, made low water in juxtaposition with the high water just mentioned. It was low water off the coast of Yarmouth, at the same time that it was high water at the mouth of the Thames. In effect, twenty hours elapsed, before high water marked the entire seaboard of Great Britain. Reference had been made to the peculiarity of the tide in the Irish Channel, and to the meeting of the tides there. It appeared to him, that there was a complete heaping up of the water, over the entire surface of the Irish Sea both on the English and Irish coasts and around the Isle of Man, at all of which places it was high water at about 11 o'clock. But it was remarkable, that at Fair Head and at Arklow, the north-eastern and south-eastern points of Ireland, there was scarcely any rise of tide. This seemed to show, that the intersection of the reversed waves took place at those neutral points, for it was low water in the offing north and south of Ireland, when it was high water in the narrow Irish Sea, and vice versâ, it was high water in the offing when it was low water in the channel. Nothing of this character occurred on the western coasts of England and Scotland, but it was to be found in the English Channel. The water was heaped up in the Straits of Dover, and at Portland the rise of tide was only 7 feet, whereas at the Land's End and at Dover it was, relatively, 20 feet and 19 feet. The same extraordinary falling off in the range of tide was also to be observed on the Norfolk coast, for off Flamborough Head the rise of tide was 16 feet, and at the mouth of the Thames it rose 15 feet, whereas in Yarmouth Roads, it was only 8 feet.

In answer to a remark from the President, Mr. Redman said, this was attributed by the Author, to the variation in depth, which, perhaps, was the real cause on that coast. Mr. Redman did not contend, that it was caused by intersection; he merely pointed out the analogous feature of the falling off in the tide at each side of England, both in the Irish and English Channels, which was not, however, traceable, as far as he was aware, on the other side of the North Sea, viz., on the French and Dutch coasts. High and low water at the entrance to the English Channel, and off Flamborough Head, would alternate, nearly, with the same periods of tide in the Straits of Dover; and Portland and Yarmouth were situated near the intersection of such reversed waves. He merely threw out the suggestion, as one probable mode of accounting for an anomalous falling off of tide. There was a difference of two, or three hours in the time of high water on the north coast of Caithness, between the Bay of Thurso and Wick, which he did not think had been referred to. He was unable to say whether it arose, in part, from the tidal wave making its way to the frith eastward, on account of the barrier of the Orkney Islands, and then returning; but it was, probably, owing to the narrow channel and to the variation in depth.

Mr. A. BREMNER remarked, that it had been stated, that the highest tides on the east coast of Great Britain, were produced by the north-west gales. He was of opinion, on the contrary, that the highest tides followed the south-west gales; such was the case, certainly, along the coast of Caithness, and in the Murray Frith. The wind from the west, south-west, and south-south-west, caused the highest tides; whilst the north-west wind reduced the rise of tide.

Mr. PETER BRUFF said, that his observations had been chiefly confined to the east coast of England. With regard to the phenomena of double tides he could not conceive it possible, that a second tide, coming from the English Channel, should take place so far north as the Frith of Forth, when it was barely traceable on the coast of Suffolk. With regard to the Frith of Forth tides, he would observe, that treble tides were recorded as a common occurrence, whereas Mr. Scott Russell had described but two. The Astronomer Royal, (Hon. M. Inst., C.E.,) in an Article on Tides, in the "Encyclopædia Metropolitana," not only stated the occurrence of treble tides, in the Forth, but that the third tide was locally termed the 'leaky.' He would direct the attention of the Members to a very instructive Paper, by Mr. Robert Stevenson, "On the Bed of the North Sea," published in the "Edinburgh Philosophical Journal for 1820," in which the effect of shoals was carefully considered,[1] and the general conclusions arrived at, were, that the shoals were largely increasing, whereby the elevation of the sea must also be seriously increased, while the sea shores and banks, on the other hand, would be proportionately endangered; and that there must be a general rising of the water level of the North Sea, upon the assumption that the same volume of water continued to flow into it. Those conclusions appeared to be at variance with the opinions generally entertained on the east coast, and also by the many eminent men who had considered the subject; inasmuch as not only ancient records but present experience went to show, that the water level of the North Sea was lower now than formerly. There was, undoubtedly, a considerable difference between the present and the former range of tide, as compared with the level of the land, and his impression was, that the sea did not now range so high as it did some centuries back. In corroboration of that view he might mention that, six hundred years ago, Norwich was a seaport of considerable importance, and its present river was an estuary, to which there were three entrances from the coast.[1] Local geologists, forty years ago, had traced the line of an ancient sea beach along the valley of the Yare towards Norwich, 40 feet above the present tide range of the North Sea, and they had discovered the same kind of shells as were found upon the adjacent beach at the present day. That fact was, in his opinion, favourable to the theory of a general lowering of the sea, but it might also be due wholly, or in part, to a general rising of the land.

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[1] *Vide* "Edinburgh Philosophical Journal," 1820, vol. iii. p. 42.

The rise of tide at Yarmouth and Lowestoft was small, compared with the coast, north and south of those places; which was a feature, he thought, little understood in the locality, no satisfactory explanation having been given of the anomaly. The rise of an ordinary spring tide at Yarmouth was from 5 feet to 6 feet, whilst a few miles to the south, it began to increase, until, at Harwich, the rise was 11½ feet, and at the entrance to the Thames, 16 feet to 17 feet. It seemed reasonable to infer, that the increase was, in part, due to the overlapping of the indirect tide from the north, by the direct tide coming through the Straits of Dover; and no doubt something was also due to the obstruction of shoals to the reflux of the tide.

Respecting harbours of refuge, he considered that was one of the practical points to which this Paper invited attention. Members would have observed, that the Government had introduced a bill in the present Session of Parliament, to assist local bodies in the improvement of harbours and navigations. There seemed to be a growing feeling in favour of improving existing facilities, which was, no doubt, a step in the right direction; instead of expending millions of money upon undertakings of extremely doubtful utility, and leaving a large extent of coast exposed, without the ordinary means of safety from casualties. He might mention an undertaking with which he had been associated, which had for its main object, the establishment of a harbour of refuge at Aldborough, on the Suffolk coast. At that part of the east coast and the immediate vicinity, very frequent and disastrous shipwrecks occurred, as since shown by the Admiralty returns of marine casualties; more total wrecks took place for several years than at any other part of the United Kingdom, only excepting the Goodwin Sands. The sea, with on-shore gales from N. N. E. to E. S. E., was so powerful, that stranded vessels could rarely be saved: they had been known to break up, and the débris to be carried a considerable distance, within an hour, or two hours, after going ashore. The casualties there had been so great, and the loss of life and property so fearful, that in 1851, a number of local gentlemen associated themselves with the view of endeavouring to mitigate the evil. A most useful and economic measure was, in consequence, prepared and submitted to the Legislature; but the Government, or rather the Admiralty of the day, notwithstanding the strong facts laid before them, not only refused their sanction to the measure, but so strongly resisted its going before a committee for inquiry, that the bill had to be withdrawn at the second reading. But within three years and a half of the time to which he had referred, as many vessels were wrecked within a few miles of the proposed harbour, several upon its actual site, as amounted in value to the whole estimated cost of the works, leaving out of consideration the large number of valuable lives that were sacrificed during the same period. He had obtained Returns from the Board of Trade, which established those results. He trusted the new light which had broken in upon official darkness, would have the effect of inducing the Government to pay more attention to this most important subject.

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[1] The entrance by Lowestoft and Lake Lothing, according to Gillingwater, was not finally closed until 1712; while the present site of Yarmouth appears, from Swinden, to have been an island until about 1347, when the northern entrance, called 'Grub's Haven,' was entirely closed. There appeared to have been a still more northerly entrance, to what was now called the Bure River, at Horsea Gap, about which no information was extant, as it had been blocked up from a remote period.—P. B.

Mr. Rawlinson said, that his observations would have reference more to the general discussion, than to the details of the Paper. Engineers had to deal with Nature as they found her; and the question of the North Sea was connected, as all other engineering works were, more, or less, with the geological features of the subject. He had been led to the conclusion, that the islands of Great Britain, being composed of some of the oldest known rocks, were now in that geological state which was allied to subsidence. The North Sea itself was a comparatively shallow sea; its greatest depth did not exceed 600 feet, and in many places it was much shallower. He attributed the formation of the banks to local causes, rather than to the washing in of débris; and he believed the Dogger Bank to be a bank, or sub-area of rock, and not a bank of silt.

The President had mentioned, that in some parts of the Baltic, near the Gulf of Bothnia, fresh-water fish were met with; and Mr. Rawlinson had been informed, that the perch and pike there grew to a larger size and were better in quality when taken from brackish, than from fresh water. The comparative saltness of the North Sea and the Baltic was in the proportion of about 2 to 1. He believed, that along the whole coast of the Baltic, both the land and the bed of the sea were rising in their level.

With regard to harbours of refuge for the eastern coast of England, he thought it would be a dangerous experiment to construct them of masonry, as at Portland, at Plymouth, and at Holyhead. They would, probably, be soon destroyed by the sea, for the coast had been, for many years past, and was still, known as a 'wasting coast.' From the Humber northwards, the rivers resembled upper 'arms,' or remnants of rivers; they ran down steep banks into the open ocean, any delta, or estuary having been washed and wasted by the wearing action of the sea, in its gradual encroachments upon this part of the English coast. He could not agree in Mr. Scott Russell's theory of the passage of the tides through the Straits of Dover; neither did he think, that the Straits had anything to do with keeping open the navigation of the North Sea, for he believed, that if the whole run of the tide on the western side was stopped, it would not have the slightest effect upon the depth of that sea.

Mr. **Hawksley** had had an opportunity of determining by experiments, in large reservoirs, the height to which waves attained; and he had found, that in the heaviest gales with which the British coast was visited, their height, in yards, was represented by the square root of the length, in yards, of any one run of wave, divided by 40, $\left(h = \frac{\sqrt{l}}{40}\right)$. That was practically true of all the waves produced in the open sea. In an unlimited space of water, the waves would, of course, attain a greater height; but all storms took a circular course, and it was almost impossible to get a clean run of more than one hundred miles in length. From all the data he had obtained he had concluded, that under any circumstances, the height of a wave was never more than 30 feet, and very rarely so much. This was an important question in considering the height of embankments in large reservoirs, above the ordinary top water level. It was for the purpose of determining the vertical height of waves, that he was led to make the observations to which he had alluded, and he had extended them to the case of the open sea, in order to make them applicable to the cases of breakwaters and sea walls.

Mr. **Hemans** said, it was remarkable to observe the great discrepancy that prevailed in the course of the discussion with regard to facts, or rather the almost entire absence of well-ascertained data. The observations of the President tended to show, that there was no current over the Dogger Bank, and the

Author had assumed the condition of the water as calm, in consequence of its being the centre of a great wave; whilst, on the other hand, Captain Burstal had asserted, that there were currents over that bank, running in both directions. As to the penetration of the southern wave of the North Sea, it appeared extraordinary to him, that in a sea of such small dimensions, and traversed by so many vessels at all seasons, no better scientific means had been furnished for collecting information. In the interesting work, "The Physical Geography of the Sea," by Lieutenant Maury, of the United States Navy, it was stated, that seamen of that country had so strongly felt the want of recorded observations, that they applied to the Government for assistance, when as many as one thousand shipowners agreed to concur in the plan of keeping an extended system of log, for a number of voyages. They succeeded in producing a map of winds, currents, and waves, which enabled them to reduce the distance between New York and Australia, from one hundred and eighty-five days to one hundred and fifty-five days; and it was estimated, that a saving of 10,000,000 dollars per annum had resulted to the American trade, from the prevention of shipwrecks, and of losses occasioned by the detention of vessels. The great importance of a chart of this kind being acknowledged, a conference was held at Brussels, to which representatives of all European nations were invited, and at which it was resolved, that the merchant services of all nations should combine in obtaining systematic observations. It did not appear, that the results of the operations of the merchant service of Great Britain were recorded in Lieutenant Maury's book; Mr. Hemans was, therefore, desirous of knowing, whether any steps had been taken, since 1853, to carry out this plan.

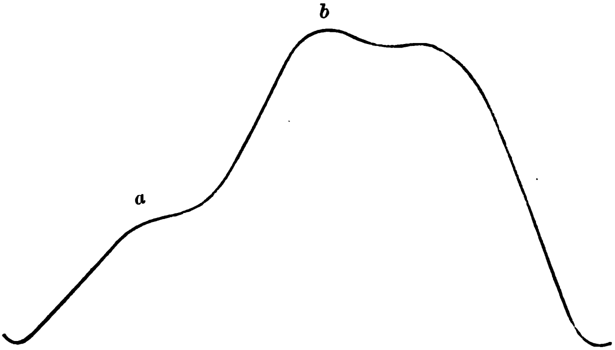
Captain BURSTAL, R.N., explained, that his information respecting the currents on the Dogger Bank, was derived from conversations with the fishermen, from whom he gathered, that there was a stream running over the bank at about 2 knots per hour, with which they trawled, and when the stream turned, they trawled back again with it. He had never made any observations, personally, upon that bank.

Mr. RALPH WARD JACKSON having, on one occasion, remained in the vicinity of the Dogger Bank for four days, could state, that there was, unquestionably, a current over the bank in both directions. The Dogger Bank was the shallowest part of the North Sea; but as the tide from the north passed over it, there must be some current, although not so strong as the great flood tide to the westward of it, which made towards Lynn Deeps, and was there met by the ebb tide from the Straits of Dover.

Mr. JOHN MURRAY said, in reply, that it would elucidate some remarks which he had to make, to refer to the Isle of Wight and the adjacent coast. The flood tide in running up the English Channel towards Dover, skirted the headland of St. Catherine's and passing on to the eastward, filled Langston and Chichester Harbours. Another branch of the stream of flood running through the Channel of the Needles and the Solent, filled Southampton and Portsmouth Harbours, meeting the former current a little to the eastward of the Isle of Wight. The Solent flood passed onwards by Calshot Castle to Southampton; but the outer stream of flood, after meeting with the former branch, turned suddenly round the east point of the Isle of Wight, and was forced forward past Portsmouth, into Southampton Inlet, making at that port a second high water. The two streams of tide united and formed one curve at Calshot Castle, but the two high waters and the two low waters were very clearly defined along the inner side of the Isle of Wight, from Cowes westward to the Needles, and from Calshot Castle westward along the coast of Hampshire, to Hurst Castle, thence to Christchurch Bay, and still further westward along the coast, to Poole.

The diurnal curve of the tide at Southampton, according to Professor Airy, as deduced from observations made at intervals of five minutes, by Officers of the Navy, was thus represented,[1]—

Fig. 1.



Curve representing the law of the rise and fall of the tide at Southampton.

a being the first high water produced from the Solent stream of flood; and *b*, the second high water caused by the stream of flood traversing the southern coast of the Isle of Wight, and then passing Portsmouth, up the Southampton Water.

In an early part of the discussion Mr. Murray had mentioned, that in the North Sea along the Danish coast, it was probable that there were two high waters and two low waters. The first, produced by the stream of flood, entered the North Sea between Norway and Scotland, and traversed the coast of Jutland to the Horn Point. The second high water, caused by the stream of flood skirting the coast of Scotland and part of England, passed from off Flamborough Head through the Silver Pit, to Heligoland; and then returned northward along the Danish coast from the Horn Point to the Skaw, or north-eastern point of Jutland. In the open sea off the Horn Point, this latter stream took a north-westerly direction, and joined the course of the ebb.

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[1] *Vide* Phil. Trans., 1843, page 46.

Before completing the present Paper, he had written to Captain Köbke of the Royal Danish Engineers, for information respecting the tides along that coast; but the reply was not received in time to be embodied in the Paper. The interesting and valuable communication from that officer gave, in detail, a series of thirty-six tidal observations taken simultaneously, in 1835, by Danish officers along the coasts of Schleswig and Jutland, from the mouth of the Elbe to the Skaw. Dr. Whewell calculated from these observations, the establishments for the different ports. But he did not in any way allude in his Second Essay on Co-tidal Lines, to the double tides which existed along the Danish coast. Mr. Murray finding these tides strongly marked in some places, and more feebly in others, had laid them down in diagrams to which he would afterwards refer. The following was the mode of proceeding adopted. On the 5th of June, 1835, at the dead of the neaps, marks were made at high water on that day at the several places along the coast, and this was the datum from which the measurements of the rise and fall of the tide were taken. Subsequent observations were made at all these places on the 9th of June, and continued till the 28th of the same month. From the 9th to the 18th, the weather was favourable, but it was not so afterwards; therefore, although he had not the later tides from the 18th to the 28th, he had those upon which dependence could be placed. At Heligoland, commencing on the 9th of June, the day and evening tides were strongly developed. Proceeding northward, at the Horn Point, the tides were diminished in their range, and at Aggerminde a still further diminution took place. Taking the average range on the 10th of June, the day of full moon, and the 14th and 15th of the same month, being the 4th and 5th transits afterwards:—

	Ft.	Ins.
At Heligoland the range was . . .	8	11
„ the Horn Point „	5	4
„ Aggerminde „	1	1½

The diurnal curve at Blaavandshuk, or the Horn Point, indicated two high waters and two low waters. They were, however, only slightly marked, in consequence of the meeting of the tides; the one stream running southward, direct from the North Sea, the other, in a north-easterly direction from the German coast. Hence the trail of these currents was to bring the detritus from Jutland southward, and from the Elbe northward, to this dangerous point of the coast. The diurnal tide alluded to occurred on the 10th of June, the day of the full moon, with a gentle north-west wind, and it would, no doubt, have been more strongly marked both at high and low water, on the 17th and 18th of June, when there was a difference of 1 foot between the morning and evening tides; but the observations being continued only over one day, did not solve the question. Proceeding northward to Aggerminde, two high waters and two low waters were more clearly developed; not so much in difference of height as at intervals of time; and more particularly, at low water.

For instance, on the 10th June :—

		H. M.	
Morning tide,	1st high water took place at	1 50	
	2nd ditto „ „	2 40	
		——	0·50 later.
Evening do.	1st high water took place at	2 35	
	2nd ditto „ „	3 25	
		——	0·50 „
Morning do.	1st low water took place at	8 5	
	2nd ditto „ „	10 30	
		——	2·25 „
Evening do.	1st low water took place at	8 5	
	2nd ditto „ „	11 30	
		——	3·25 „

This was even felt as far as the Skaw, but the intervals of time between the two high waters and the two low waters were considerably less than at Agger. Many fatal shipwrecks annually took place, in consequence of the want of information by mariners, of the sets of the tidal currents on this dangerous part of the coast.

Respecting Mr. Scott Russell's observations on the tides of the Frith of Forth, he thought a more simple theory could be given. He had no doubt of the fact of there being two high waters in that estuary, nor had he any reason to question the hump in the diurnal curve, alluded to by Mr. Scott Russell, as occurring during one tide, and its obliteration on the next. He conceived these two high waters were produced by the streams of flood entering the frith, in the manner described in the Paper. There were three great streams of flood which entered this frith. The first, after splitting on Kinnaird Head, took a course parallel with the coast of Aberdeen for the River Tay and the Bay of St. Andrew's, and thence hugging the coast, it entered the Frith of Forth. The second stream of flood also ran parallel with the coast of Scotland, outside the Bell Rock and the Isle of May, and passed into the frith; but as the one ran at a quicker rate than the other, it united with it on entering that estuary, and the effects of the former stream were brought into one, which made high water along the northern shore of the frith. The third stream of flood from the North Sea ran in the deep water outside of the Long Forties, and splitting off St. Abb's Head, likewise threw a branch into the frith, making high water along its southern shore. These two streams caused the two high waters, and taking similar courses on the ebb as on the flood, the two low waters. But Mr. Scott Russell had observed, that would not explain the reason of the evening and the morning tide, the evening tide being, at one period of the year, the highest, and the morning tide being the lowest, and vice versâ in the autumn. Mr. Murray thought the difference arose, not so much from the season of the year, as from the declination of the moon. At most places the evening tide was the highest to the 10th, or 12th of the month; but from the 18th to the 25th, the morning tide was, generally, the highest.

Referring now to the stream of flood which split off St. Abb's Head; assuming that to be a morning tide, with less range than the evening tide, and that it made the first series of high waters in the Frith of Forth. It took twelve hours to arrive at Heligoland, and, consequently, it became an evening tide there; running thence northward, the stream changed to that of ebb, and united with the coming tide which now entered the Frith of Forth, making the second high water in that estuary. Performing that operation a second time, it again caught the morning tide, causing the hump in the diurnal curve to be longer visible; hence, the alternate hump, and its obliteration. Thus, the Dogger Bank of the North Sea caused not only the double tides on the coast of Denmark, to act in a similar manner on the Danish coast, as the Isle of Wight did on that of Hampshire, but it produced effects on the opposite coast so far off as the Frith of Forth.

Great praise was due to Dr. Whewell, for drawing attention to the co-tidal lines. His chart was based on observations made at thirty-four different places round the British Isles. He considered it advisable to have a second series of observations, and in 1835, application was made to the Admiralty, and through that department, with the different States of Europe, and of America, for co-operation. From the observations thus procured, more accurate co-tidal lines were obtained, so far as regarded the different lines of the coast. But Mr. Murray, having contoured the bottom of the North Sea, wherever reliance could be placed on the soundings, was led to differ from Dr. Whewell in the form of the co-tidal lines of that sea, which he conceived must be affected by the inequalities of the bottom. With a chart so contoured, and the direction of the streams of flood marked upon it, he had come to the conclusion, that near the Ameland Bank, lying off the Danish and German coasts, there was no rise, or fall of tide; and he thought the Admiralty should solve this question as the late Captain Hewett had done that off the coast of Holland.

Mr. Scott Russell had informed the Meeting, that he had constructed a model of the bottom of the North Sea, contouring it from the best charts, and by pouring in water at the north and south ends, he had illustrated the course of the tide from the Straits of Dover up to the Frith of Forth. He might be permitted to suggest to Mr. Scott Russell, that sand should have been put into the model, representing the principal banks, which, he thought, would assume a very different form, if the waters took the course indicated by that gentleman.

Mr. Ward Jackson had spoken of the impossibility of the Dogger Bank ultimately becoming an island and a fit spot for a harbour of refuge. Most certainly this would not occur for some time to come; it was, however, a fact, that ships of war had ridden for twenty-four hours under the lee of the Dogger Bank. He had also stated, that he conceived the Straits of Dover to be the safety-valve of the North Sea; but Mr. Murray was of opinion, that formerly, the waters of the North Sea communicated with the English Channel in a different direction. When this was closed by the chalk formation, it was probable, that the waters of the English Channel passed direct into the Paris basin up the valley of the Seine, and ultimately, communicated with the southern part of the North Sea, when a breach was made in the chalk, through the present Straits of Dover.

Mr. Jackson had alluded to the statement of Admiral Beechey, that when it was low water at Lynn Deeps, it was high water at Dungeness, which destroyed the theory of Mr. Scott Russell, as to the water passing through the narrow channels and extensive shoals lying off the coast of Norfolk.

The President had drawn attention to the rise and fall of the water in the Baltic. When Mr. Murray was at Copenhagen, a valuable series of observations, extending over a period of twelve years, was brought under his notice, which had been made at the Three Crown Battery, at the entrance of the harbour. He had condensed them into months during the two years 1858–9, and had obtained the following results; the datum being the level established by the Government, and called 'Daily Water.' (D. W.)

1°. That during eight months in the year, the water varied from 1·885 feet + D.W., to 1·623 feet − D.W. = a range of 3·508 feet.

2°. That during three months in the year, the water varied from 2·098 feet + D.W., to 1·885 feet − D.W. = a range of 3·983 feet.

3°. That during the remaining month of the year, the water varied from 3·147 feet + D.W., to 3·109 feet − D.W. = a range of 6·256 feet.

4°. That during the last-named period, for four, or five days of the year, the water varied from 4·42 feet + D.W., to 4·196 feet − D.W. = a range of 8·616 feet.

These effects were produced from the action of the waves on the surface of the water in the North Sea and in the Sound, on the one hand; and in the Baltic, on the other.

Another point brought under his notice when at Copenhagen, was the saltness of the water in the chalk. A tunnel had been driven across the interior of the harbour, for the purpose of laying down the water pipes, and great difficulty was experienced in executing that tunnel, on account of the quantity of water in this chalk formation. Mr. John Aird, the contractor for the work, informed him, that the water met with at a depth of 30 feet under Daily Water was salt. It should be mentioned, that the water in the harbour was only, at times, brackish, but when the current ran strong out of the Baltic, it was nearly fresh. Mr. Murray was at a loss to account for the saltness of the water, at that depth in the chalk.

In 1820, the late Mr. Robert Stevenson, of Edinburgh, wrote a Paper "On the Bed of the North Sea," which was published in the "Edinburgh Philosophical Journal."[1] In 1834, he also communicated a Paper to the British Association, at Edinburgh, "On the Relative Level of the Land and Sea, and on the Waste and Extension of the Land," which, however, was not printed in their Transactions, because it had never been completed. His son, Mr. Thomas Stevenson, had contributed a Paper to the Royal Society of Edinburgh, "On the Destructive Effects of the Waves of the Sea on the North-east Shores of Shetland,"[2] from which Mr. Murray read the following extract:—

> "On the Bound Skerry of Whalsey, which is only exposed to the waves of the North Sea or German Ocean, he had found, on first landing in 1852, masses of rock, weighing 9½ tons and under, heaped together by the action of the waves at the level of no less than 62 feet above the sea; and others, ranging from 6 to 13½ tons, were found to have been quarried out of their positions in situ, at levels of from 70 to 74 feet above the sea. Another block of 7$\frac{7}{10}$ tons, at the level of 20 feet above the sea, had been quarried out and transported to a distance of 73 feet from S.S.E. to N.N.W., over opposing abrupt faces as much as 7 feet in height."

Mr. Harrison had intimated the probability of the Dogger Bank being formed of chalk, but Mr. Murray was not aware that any borings had ever been made to prove the fact. Whatever might be the nucleus of the bank, there could be no doubt, that the great mass was composed of sand and other detritus brought there by tidal currents. The President had asked, whence the sand and débris to which the formation of that bank was attributed, could have been derived. In the works which Mr. Murray had carried on, for a number of years, upon the eastern coast of

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[1] *Vide* "Edinburgh Philosophical Journal," 1820, vol. iii., p. 42.

[2] *Vide* "Proceedings of the Royal Society of Edinburgh," 8vo., vol. iv., p. 200.

England, he had studied the effects of the waves, and he had found, that in calm weather, and with off-shore winds, the sand accumulated along the coast at the line of high water, but that it was swept away by on-shore gales. After storms with certain winds, many acres in extent of sand had been deposited between high and low water, which in a few tides, afterwards, were dispersed and carried elsewhere by tidal waves and currents. In that part of the coast to which he alluded, these accumulations were invariably carried southward along the coast. In connection with this subject, he would take a geological view of the case, as applied to England, and would endeavour to show, that all the débris deposited on its eastern side was brought from a northern source. He would first draw attention to the state of England after the old red sandstone was deposited. First, there was the porphyry of the Cheviot Hills and Holy Island; secondly, the clay slate, &c., of Cumberland and Westmoreland; thirdly, the Silurian and Cambrian rocks of Wales; fourthly, the granite and the later formations of Cornwall and part of Devonshire. All these formed, with the outlying granite rocks of Mount Sorrel, the primary isles of England, which might be imagined rising above the surface of the ocean, with the tides and currents acting upon them. Then followed the successive deposits of the mountain limestone, of the millstone grit, and of the coal measures. When the latter were deposited, any good geological map would prove, that Northumberland was then connected with Cumberland and Westmoreland, but that a strait existed at Liverpool which separated these lands from the northern part of Wales. A few islands had then been formed at the head of the Bristol Channel, amidst which the streams of flood and ebb had their course, meeting and separating from the other great stream from and to the Atlantic ocean, along the southern coast of Cornwall. At that time, no part of the eastern coast of England was in existence. Then succeeded the new red sandstone, which must have had its source from the north, and meeting with the stream of tide up the Irish Channel, filled up the strait between the northern primary isle and that of Wales. There was only a small quantity of the new red sandstone deposit to be met with in the eastern parts of Devonshire. The lias and oolite had also a northern origin, and were deposited along the eastern coast of England, until the primary consolidated isles became united, and were afterwards compacted into a mass by the chalk deposited also along the eastern part of England. Subsequently at a later age the deposits of Norfolk and Suffolk took place, which, unquestionably, came from a northern source. Before leaving this part of the subject, he would call attention to the course of the Severn, which, running from the Plinlimmon Mountains, must, at one time, have discharged its waters into the strait between Wales and the primary isle of Cumberland and Westmoreland. When the new red sandstone filled up the strait, the course of the Severn was lengthened and its waters fell into what was then the southern part of the North Sea. After the deposit of the lias and the oolite the Severn was still further prolonged, and had its outlet into the Bristol Channel. From a study of this subject, he had come to the conclusion, that the detritus of the present day also came from the north, and had formed the extensive shoals on the coast of Norfolk, as well as the Dogger Bank. It had been stated, that there were no currents over that immense deposit, but inasmuch as the bank was covered with water, the flood and the ebb continually passing backwards and forwards, must necessarily create currents, although, no doubt, they were feeble, in comparison with the great sweep of tide running from Flamborough Head south of the Dogger Bank, towards the mouth of the Elbe and the southern part of the North Sea.

With regard to the manner of colouring charts, this was, in Mr. Murray's opinion, of much less importance, than properly contouring them, and further distinguishing some of the principal contours, by stippling them into darker shades where the deep water existed; then if coloured, the outlines would be more forcibly impressed upon the memory than simple contour lines.

He would finally allude to another point. If a longitudinal section of the coast of Scotland and England were made, from Kinnaird Head to Lynn Deeps, and the rise of tide, at some of the leading points, marked upon it, it would be found, that at Kinnaird Head, the range was 11 feet, while off the mouth of the Tay the rise was 16 feet; the greater range being caused by the momentum given to the current and its being forced into that estuary. Again, at St. Abb's Head, the range was only 14 feet 6 inches, and continuing its course up the Frith of Forth, the rise at Leith was 16 feet 6 inches; and at Queensferry 18 feet. From St. Abb's Head to Tynemouth, the range of tide was increased from 14 feet 6 inches to 15 feet 6 inches. At Flamborough Head it was 16 feet, at Spurn Point 18 feet 6 inches, and in Lynn Deeps 23 feet. He could account for the rising of the water, in its passage from the deep parts of the North Sea off the coast of Aberdeen to Lynn Deeps, by the momentum given to it. If, therefore, the half-tide line between those two places was a level line throughout, there was a rise of 5 feet 6 inches at Kinnaird Head against 11 feet in Lynn Deeps, or 5 feet 6 inches above the level of the North Sea on the coast of Scotland. On the other hand, if the low-water line was level, then there was a difference of 11 feet between these two places. He could imagine the high water rising above its level, but not that the water from the shoals lying off the coast of Norfolk should run in an ascent to the deep water of the North Sea.

In conclusion, he expressed an earnest hope, that Engineers having charge of harbour works, in connection with railways, would take the levels from the Ordnance bench marks to the established high water of the place, and communicate the results to the Institution. The question, whether a level line existed along the coasts of England and Scotland, at low water, or at half-tide, might then be solved in a satisfactory manner, and it might lead to further investigation as to the deep water of the North Sea, free from the influence of the headlands and shoals of the coast.

Mr. BIDDER,—President,—observed, that, no doubt, Civil Engineers were bound, as one of the most interesting features of their profession, to take notice of natural phenomena, but the object of the Institution was to bring those phenomena within practical application. It was of little importance to them, as Engineers, to know in what manner the Dogger Bank had been formed, or whether it was rising, or subsiding, provided that neither effect was likely to take place for many generations. But it was important to consider the phenomena of the North Sea, with the view of ascertaining the practical deductions which could be drawn from them. In an engineering point of view, the North Sea possessed features of great interest, and its phenomena were worthy of attentive consideration. It commenced at Dover Straits, between which and the sea, the shores, were, essentially low-lying shores, and they were protected by outlying shoals; whilst on the corresponding side of the Baltic, the lands were high. From the sea it continued to the coast of Sweden, and to Norway; the former, a rocky coast, and dangerous to approach, because of the great number of sunken rocks, whilst the coast of Norway, from Christiania to the Naze, although also rocky, was, perhaps, one of the safest in the world, because outside of the line of coast, there was not a rock, or shoal of any description. Ships overtaken by W.S.W. gales, the prevailing wind, and however disabled, could always find shelter in the forty, or fifty harbours which lay between Christiania and the Naze, a distance of about 130 nautical miles; and the charts and surveys were most accurate. He had run in himself without a pilot, with perfect security, and within five minutes afterwards, the yacht was in water as smooth as a millpond.

Another feature of general interest in the North Sea, to which he would incidentally allude, although not quite germane to the present subject, was the prodigious fisheries which were established there, which contributed more to the wealth of Europe than any deposits of gold. The enormous produce of the fisheries,—produce which all might reap without sowing, and which was inexhaustible,—was specially remarkable on the coast of Norway, where from twenty to thirty thousand men were employed, within a comparatively short distance, catching herrings, which came in shoals so numerous as, sometimes, to drive one another on shore. The shoals of fish did not always pursue the same track, nor appear on the same part of the coast; and as it was of great importance, that the fishermen should be apprised of the direction in which they approached, science had, within the last few years, been brought to bear, in spreading that information along the coast, by means of the electric telegraph.

It was scarcely possible to treat of the North Sea, without some consideration of the Baltic. He had listened with surprise to the remarks of Mr. Murray, with regard to the diurnal variation in the tide, at Copenhagen, amounting to as much as 8 feet; as the whole effect must proceed from the waves of the main ocean, inasmuch as lunar influences could not affect the tide in narrow seas. The President thought this variation could only be produced by high winds, and at certain seasons of the year; and there was one feature on that coast which might have some practical effect in causing it. The east wind, which was the prevailing wind, was also that which exhausted the Baltic. On the coast of Denmark, as contradistinguished from that of Holland, high water and high sea were invariably accompanied by an off-shore wind, the on-shore wind bringing low water. The consequence was, that works thrown out to protect any reclaimed lands were less exposed to danger, than on most other coasts. There was another point for consideration in the Baltic, whether there was a permanent flow of water from it into the North Sea. An idea had been entertained, upon what would appear to be sufficient data, that the Baltic was altering both its level and its degree of saltness. For his own part, he thought the flow of water in and out of the Baltic, was nearly the same. Looking to the rivers that flowed into it, compared with the area of that sea, and the large amount of evaporation taking place during the summer months in those latitudes, where the sun was more powerful than in this country, and considering also, that during winter, the waters both of the sea and the rivers were frozen up, he had arrived at the conclusion, that there was no surplus flow of water, to any extent, from the Baltic to the North Sea, and that all the currents through Elsinore were owing to the prevailing winds.

With regard to the tides, the best data were those given in the maps designed by Dr. Whewell, published under the authority of Professor Airy, with the "Encyclopædia Metropolitana," and copied in Johnston's "Physical Atlas." They showed, that the tides upon the east coast were entirely owing to the north wave coming round Pentland Firth; whereas the tides on the coast of Holland, were due to the wave travelling up the English Channel. The tides on the eastern coast were remarkably uniform, with the exception of those parts where they were influenced by local circumstances, as at Yarmouth, for instance. The wave came through the mouth of the harbour for a long distance, without any great variation of height; whereas over the general surface of the harbour, the wave was lessened. The tidal wave came with undiminished height, from the Pentland Firth and the Shetland Isles to the east coast; as also did the wave from the English Channel, along the Dutch coast. The height of the wave on the east coast, might be taken at from 15 feet to 18 feet, and on the Dutch coast at from 6 feet to 12 feet. That great height was due to the local circumstances of the Schelde and the Elbe, where the north tide aided the western tide. He thought, that the extraordinary practical results of the wind tides had not been sufficiently estimated. The prevailing wind in the North Sea was that from the W. S. W., alternating, in high gales, to N.W.; and it was that wind which heaped up the water on the Dutch coast to an extraordinary height, reacting upon a certain part of the coast of Norfolk, which was the nearest to the Dutch coast. This was shown, practically, in a remarkable manner. In the Thames, the banks were regulated to a height of about 4 feet above high water, which experience had proved to be sufficient; whereas in the Schelde and the Elbe, a height of even 13 feet had been found insufficient. In fact, all along that coast, as far as Jutland, the minimum height at which banks could be safely erected to shut out flood water, was from 11 feet to 13 feet. This was owing to the north-west wind being an on-shore wind there, whilst it was, on the contrary, an off-shore wind in England; and it produced a great congestion of water in the narrow part of the North Sea. Although the Schelde and the Elbe were rivers which contained a larger amount of land water than any English rivers, and drained a much larger area, yet, owing to the small rise of tide, the depth of the streams into which they flowed was much less than upon the English coast. This, he thought, was to be attributed to the small rise and fall of tide on that coast, compared with the English coast.

As regarded the Dogger Bank and the question of currents over it, he could only speak from experience. There were, no doubt, currents on that bank, because it was impossible, at any season, to find water of any depth without some current; but he believed the current must be very light; and certainly, it could not be the means of carrying the sand from the shore. There were also wind currents, for with a large congestion of water in a westerly gale, there must be water to supply that demand, and it must flow in one direction. But having been becalmed upon the Dogger Bank, he could positively assert, that he had fished there, with the plumb-lead overboard, to ascertain the depth for the bait, and he had never been able to ascertain the existence of any perceptible current.

It was quite evident, that there must be a great mechanical action going on in the North Sea, as there was a considerable current running to the east, from the Dover coast to Christiania and the Naze. It was a constant current, of which the intensity varied with the prevailing winds. He held it to be a great mechanical result produced by mechanical means, and he could see no other cause for it, than the prevailing wind, which being W. S. W., created a mechanical effect sufficient to maintain the current in that direction.

The question of harbours of refuge was of great national importance, and it ought to be carefully discussed in the Legislature. There was no sea more dangerous than the North Sea, and none, probably, where the loss of life and property was so great. The rates of insurance were higher there than elsewhere, varying from 10*s*. per cent. in the summer season, to 60*s*. per cent. in the fall of the year. Much of the risk was owing to the character of the vessels employed, which were incapable of weathering a lee shore; but he doubted, whether harbours of refuge would conduce to lessen the loss. In any case, harbours of refuge ought to be established in the North Sea, for protection to vessels in time of war. But for the latter purpose, they would have to be constructed in localities, distinct from the harbours required for sheltering vessels in stress of weather.

As to contoured maps; no doubt, they would, sometimes, be useful, but not to the extent which had been imagined. But it was most essential that maps should be correct. In approaching Heligoland, whether bound for the Elbe, or the Eider, a vessel taking a wrong direction would be exposed to very great risk. He had himself been in vessels which, misled by inaccuracies in the charts, had taken the wrong side of Heligoland. The Americans had set a useful example in this respect, and one which ought to be carried out by British masters, each one carefully collecting information as to the soundings and currents of the seas he navigated. The subject raised by the Paper was of the greatest interest; but he felt, that full justice had not yet been done to it. Much information of a practical character was still required; he hoped, therefore, that the subject would, hereafter, be resumed, with more satisfactory and complete data.

March 19 and 26, 1861.

GEORGE PARKER BIDDER, President, in the Chair.

The discussion upon the Paper, No. 1,037, "On the North Sea," &c., by Mr. J. Murray, occupied the whole of these evenings, to the exclusion of any other subject.

At the Meeting of March 26, in pursuance of the notice on the card of the Meetings, it was proposed, and resolved unanimously:—

"That in order to insure a fuller attendance of Members than could be obtained on Easter Tuesday, the Meeting be adjourned until Tuesday evening, the 9th of April."

April 9, 1861.

GEORGE PARKER BIDDER, President, in the Chair.

The following Candidates were balloted for and duly elected:—FRANCIS GILES, JOHN CHARLES PEARCE, and RICHARD PRICE WILLIAMS, as Members; ROBERT CRAWFORD, CHARLES ERNEST HOLLINGSWORTH, Captain BEDFORD CLAPPERTON TRYVELLION PIM, R.N., HURRYCHUND SADASEWJEE, THOMAS HARDY TAYLOR, and GEORGE VAUGHAN, as Associates.

The discussion upon the Paper, No. 1,037, "On the North Sea," &c., by Mr. J. Murray, was resumed, and occupied the whole of the evening, to the exclusion of any other subject.

April 16, 1861.

GEORGE PARKER BIDDER, President, in the Chair.

No. 1,036.—"On the Floating Railways across the Forth and Tay Ferries; in connection with the Edinburgh, Perth, and Dundee Railway." By William Hall, Assoc. Inst. C.E.

The object of the Floating Railways, a description of which forms the subject of this Paper, was to provide a more rapid and efficient means for the transit of goods across the Forth and Tay Ferries, than that in operation by the ordinary ferry boats. These boats were in connection with the Edinburgh, Perth, and Dundee Railway; and, previous to the construction of the works under consideration, it was the custom, on the arrival of the train at Granton, to remove all goods for the North, from the waggons, into the boats lying alongside the pier, and on reaching Burntisland, again to transfer them into waggons. The same changes had also to be repeated at the Tay Ferry. This operation involved much loss of time, and great expense, besides often causing breakage and damage to the goods, thus being also the source of frequent litigation to the railway company. It became, therefore, desirable to establish an unbroken chain of communication between Edinburgh and the country north of the Tay, by which goods, and even passengers, if required, could be conveyed across the ferries, without removal from the waggons.

The ferry on the Forth is between Granton and Burntisland, a distance of five miles and a half; and that on the Tay is between Ferry Port-on-Craig and Broughty, a distance of seven-eighths of a mile. Both estuaries are open to the North Sea, and are, at times, exposed to very stormy seas, which the best passenger steam boats shrink from encountering.

In the design of this work, one of the chief difficulties to be overcome, arose from the variation in the level of the water, the difference between high and low-water spring-tides being 16 feet. It follows, that the deck of a vessel, level with the fixed rails on the quay at high water, will be 16 feet below them at low water. It was, therefore, essential, that means should be devised for readily transferring the waggons, with their contents, from the quay to the vessel, at all states of the tide. Several plans were proposed, among others, hydraulic and steam cranes, to lift, or lower the waggons; but it was considered, that this would be too slow a process, and would be liable to damage the waggons. The previous Engineer to the Edinburgh, Perth, and Dundee Railway Company, the late Mr. Thomas Grainger, furnished a design to effect this object, consisting of girders 100 feet in length, having one end hinged on shore, and the other attached to a floating caisson, to rise and fall with the tide. This plan would, no doubt, have answered remarkably well, in less exposed situations; but at both these ferries, it would have been necessary to erect protecting works, by the construction of expensive piers and jetties.

There have been one, or two undertakings, for a somewhat similar purpose to that now under consideration. One of these, the floating bridge across the Hamoaze, designed by the late Mr. Rendel, forms the subject of a valuable Paper read before the Institution.[1] In this case guide chains were employed, and the ferry was comparatively short; nor did it form, as in the present instance, a connecting link between portions of a railway. The other was the steam ferry over the Nile, at Kaffre Azzayat, designed by the late Mr. Robert Stephenson, a description of which was laid before the Institution, by Mr. T. Sopwith, (M. Inst. C.E.,)[2] was constructed some years later than the work under consideration. It also was guided by chains; but it was not necessary to give the boat the sea-going qualities, which were indispensable to that at the Forth Ferry.

In the two instances forming the subject of the Paper, the desired object was successfully accomplished, by the works about to be described, which were designed by Mr. Thomas Bouch, (M. Inst. C.E.,) the Manager and Engineer to the Railway Company, and were matured and executed under his instructions, by the Author.

The works at the Forth Ferry, (Plate 4,) may be thus described:—On the east, or sea side of the piers at Granton and Burntisland, there is a slipway, at an inclination of 1 in 6, constructed of solid masonry, extending from the top of the quay, which is 5 feet above the level of high-water spring-tides, down to the level of low water. Upon this slipway are laid four balks of timber, 14 inches square, in which the rails are fixed, and the wheels of a heavy travelling platform move up and down the slipway. The outline of this platform is wedge-shaped, the upper surface being always horizontal. It is 65 feet in length and 21 feet in breadth. It consists of a massive framework of wood, having four main longitudinal timbers into which the rails are sunk. The platform rests upon twenty-four strong cast-iron wheels, each 2 feet 6 inches in diameter, and instead of the flange being on the inside of the rim, it is cast on the middle, thereby enabling the wheel to bear evenly on both sides of the rail. To the end of this travelling platform are attached, by means of universal joints, (which will, hereafter, be more particularly described,) four wrought-iron trough girders, each 35 feet long, and 24 inches deep in the middle. These girders span the distance between the platform and the stern of the vessel, affording a sufficient clearance in the greatest swell of the sea, between the keel of the vessel and the slipway. About midway along the platform on each side, are fixed two vertical standards, supporting a staging 18 feet in height. On this staging, and immediately above the standards, there are two powerful winch crabs, fenced round for the protection of the men in charge, to which access is obtained from the platform by a wrought-iron ladder. The crabs are for the purpose of raising, or lowering the girders, on the arrival, or departure of the vessel. This is effected by means of a chain with links of iron $\frac{3}{4}$ths of an inch in diameter, passing from the crabs to two derricks, one on each side of the platform, and thence over sheaves fixed to a cross beam of wrought iron 12 inches deep, with angle iron at the top and the bottom, secured to the front end of the girders. To balance the girders when resting on the vessel, a heavy weight is attached to each end of the chain for lifting the girders. The ends of this chain pass over the barrels of the crabs, and being guided between the timber standards, the weights rise, or fall according to the movement of the vessel. To the platform is attached a chain cable $1\frac{1}{8}$ inch in diameter, connected with a steam engine and gearing fixed on the quay, which raises, or lowers the platform, to adapt its level to that of the vessel, according to the state of the tide. To provide for the safety of the platform in the event of the fracture of this chain, two lines of racks, with teeth cast in them, are laid along the surface of the slipway. Palls attached to the axles of the wheels work into these racks, which can be governed at pleasure from the surface of the platform. The ends of the wrought-iron girders, where they rest on the vessel, fall in between guiding pieces fixed on the deck, and extend a distance of 3 feet 6 inches along it. This is to allow for the movement, or longitudinal separation of the vessel from the platform. The girders have, at their extreme ends, steel points turning on hinges, which slide on the rails on deck. Similar steel points are also attached to the pier ends of the main timbers of the platform. These, in both cases, are to provide an easy inclination, and prevent an abrupt transition of the waggons to, or from the vessel. This portion of the work is, of necessity, constructed so as to give the greatest freedom and full play in the action of each part.

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[1] *Vide* Transactions Inst. C.E., vol. ii., pp. 213-227.

[2] *Vide* Minutes of Proceedings Inst. C.E., vol. xvii., pp. 53-62.

Owing to the peculiar form of the wrought-iron girders, the Author was induced to make some experiments as to their strength, the results of which are shown in the following Table:—

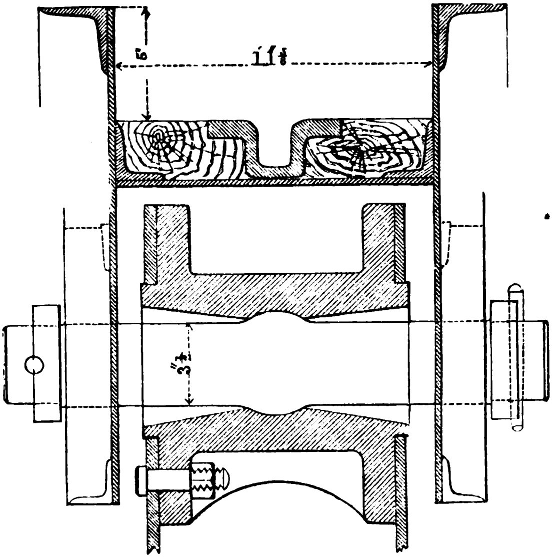
Section at the Middle of the Girder.

Pressure, in Tons.	Deflection, in Inches.	Increase of Deflection.	Remarks.
2 Tons.	·218	..	
4 „	·281	·063	
6 „	·406	·125	When 17·75 tons pressure were taken off, the girder returned to its former position.
8 „	·531	·125	
10 „	656	·125	
12 „	·718	·062	
14 „	·781	·063	
16 „	·874	·093	
18 „	·968	·094	
20 „	1·000	·032	
22 „	1·093	·093	
24 „	Experiments not carried further.		

A hydraulic machine was used in testing, and the pressure was applied in the centre of the girder, upon a piece of timber, resting upon the connecting plate between the side plates; the distance between the points of resistance being 31 feet.

It has already been observed, that the platform is made to move up and down the slipway, so as to adapt its level to that of the deck of the vessel; the wrought-iron girders resting on the vessel at one end, and being attached to the platform at the other. In this relative position of the platform and the vessel, the one a stationary and the other a floating body, it will at once appear, why the girders were attached to the platform by the description of hinge before referred to as the universal joint, a section of which is shown in Fig. 1; (page 380.) There are four of these universal joints. Each consists of a bolt, or pivot, 3½ inches in diameter, the middle of which is ball-shaped, and works in a corresponding portion of a cup, or socket. This socket is circular, and is made in two parts, having a projecting collar and flanges, which are clipped by, and are bolted to the plates, fixed to the main longitudinal timbers of the platform. The socket is shaped in a radial form to allow full play to the bolt, or pivot, and to give free action to the girders at their extremities, to the extent of 3 feet on each side. By this means, a range of position is obtained to the extent of 6 feet, to allow for the pitching, or rolling of the vessel, besides the greater vertical range requisite to adapt the girders to the deck of the vessel, at its arrival, or departure.

Fig. 1.



Universal Joint.

On the quay there is a stationary steam engine of 30 H.P., similar to a locomotive with the wheels removed. This engine is used for raising and lowering the travelling platform, according to the state of the tide, and for drawing the waggons off, and on board the vessel. The gearing in connection with this engine is shown in Plate 4. On the crank shaft of the engine is fixed a pinion working into a wheel, on the shaft of which are three winding drums, one placed in the middle of each line of rails, and one in the intermediate space. This latter is gauged to serve as a main centre line, thus giving three lines in the space of two, and superseding the employment of switches, or shifting points. The winding drums are each 2 feet 10 inches in diameter, with flanges of greater diameter having wood bolted on the periphery, round which there is a wrought-iron friction band, acting as a break. The engineman works either of these breaks with his foot. The drums can be thrown in, or out of gear, at pleasure, by means of clutches worked by handles, also within reach of the man in attendance ; when out of gear, the drums, of course, revolve loose upon the shaft. The speed of the engine is decreased by toothed wheels and pinions, seventy strokes of the engine giving thirty-five revolutions to the drums, and by other intermediate wheels and pinions, three and one-fifth revolutions to the chain wheel, which is 2 feet in diameter, and has wrought-iron teeth working into a flat link chain. This chain is joined to the cable chain, previously mentioned, the latter being attached to the moveable platform, to raise, or lower it according to the state of the tide. The weight of the platform is about 70 tons, and it is moved up and down the incline, at a velocity of 18 feet per minute.

The steam-vessel for conveying the goods traffic across the Forth, named the 'Leviathan,' was built by Mr. Robert Napier, (M. Inst. C.E.,) of Glasgow. Being of too great a width to pass through the Caledonian Canal, it was brought round by the north of Scotland to its destination in the Frith of Forth, the Author, with two, or three friends, being on board. Considering her peculiar construction, being so flat bottomed, this voyage may be cited as a good proof of her sea-going qualities, as she encountered a violent storm, which proved fatal to an Indiaman wrecked near her course. The vessel, which is constructed of iron, is 172 feet long, 54 feet 3 inches in breadth over, and 34 feet between the paddle wheels, with 11 feet depth of hold. The breadth on the deck at each end is 17 feet 6 inches. The draught of water when loaded, is 6 feet 6 inches, and when unloaded, 4 feet 9 inches. The paddles are 22 feet 4 inches in diameter, and 10 feet in breadth. The vessel is propelled by two steeple engines, one on each side, close up to the paddle boxes. The engines are disconnected, each working its own paddle, the space between them being left free for the waggons. The collective nominal power amounts to 210 H.P., the cylinders being 56 inches in diameter, and with a stroke of 3 feet 6 inches. There are two boilers, working at a pressure of 8 lbs. per square inch, and two funnels, one on each side of the vessel. Both ends of the vessel were originally of similar construction, each having a rudder, with the view of saving the time that would be otherwise lost in turning. In working the vessel, however, it was found desirable for safety to place buffers at one end, to prevent the waggons from going overboard. This, consequently, became the stern, and then the rudder was removed from the other end, or stem. The steering wheel is placed on the centre of a gangway extending between the paddle boxes, at a height of 13 feet above the deck; and chains pass from the wheel along the gangway, traversing each side of the vessel to the rudder. The rails are sunk into longitudinal timbers flush with the surface of the deck. There is room for three lines of waggons, the end one on each line being scotched, to prevent its shifting.

The description of rail used throughout, is the inverted bridge rail, the same as that laid on Granton Pier, weighing 53lbs. per lineal yard. This form of rail is peculiarly well adapted for piers and structures of this description, as a surface is obtained free from any obstruction. Two lines of rails forming continuations of the main lines, are laid along the whole length of the slipway, the platform, and the girders. On reaching the vessel, they diverge into three lines, in order to give greater space for waggons. The deck of the vessel is thus converted into a moving length of rail, virtually extending the railway across the estuary, and hence the term 'floating railway.'

The cost of the works on the Forth, at Granton and Burntisland, was :—

	£.	s.	d.	£.	s.	d.
Slipways	4,000	0	0			
Platforms	5,200	0	0			
Stationary Engines and Gearing	800	0	0			
				10,000	0	0
The 'Leviathan,' with Rails and Stores ready for Sea				16,226	0	0
Total Expenditure £				26,226	0	0

The disbursements, or working expenses, including repairs, &c., for six months from February 1st to July 31st, 1860, were :—

The 'Leviathan.'	£.	s.	d.	£.	s.	d.
Wages of Captain, Crew, Engine and Firemen	629	16	2			
Coals, 1,664 tons 17 cwt.	424	17	8			
Oil, Tallow, and Waste	60	5	4			
Ropes and Repairs to Steamer	189	15	4			
				1,304	14	6
Stationary Engines and Machinery on both sides of the Forth.						
Wages of Enginemen and Porters	457	14	0			
Coals, 223 tons 15 cwt.	56	16	11			
Oil, Ropes, Repairs, &c.	253	3	0			
				767	13	11
Total disbursements for Six Months £				2,072	8	5

The above includes a double shift of men for the 'Leviathan,' and also enginemen and labourers, the latter being also employed on the passenger boats during the same period.

The 'Leviathan' generally makes four to five double trips in the day of twenty-four hours, and it can take from thirty to thirty-four waggons at a time, often carrying two hundred and forty waggons per day, which is at the rate of 75,120 waggons per annum.[1] The time occupied in making the single trip is about twenty-six minutes, and the operation of loading and unloading takes an additional five, or eight minutes. During the six months from February 1st to July 31st, 1860, the number of trips made was fifteen hundred and forty-six, equal to 8,503 miles, and the number of waggons carried was 32,712, equal to 21·15 waggons per trip. The rate for the carriage of minerals and other heavy goods is one shilling per ton. The opening of this work has been the means of introducing into Edinburgh, the coal from Fife, which before was unknown in that market.

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[1] Mr. Anderson states, in a letter to the Secretary of the Institution, dated the 15th April, 1861, that during the preceding six months, 37,618 trucks were conveyed across the Forth.

It is unnecessary to enter minutely into the particulars of the works on the Tay Ferry, further than to remark, that they were constructed after those on the Forth, and experience in the working of the latter suggested one, or two improvements.

The inclination of the slipway was made 1 in 8, instead of 1 in 6, and it was formed of timbers resting upon wooden piles; in other respects the works are similar. The distance of the ferry, as already stated, is seven-eighths of a mile.

The steam-vessel 'Napier' is much smaller than that on the Forth. Its length is 140 feet, breadth 40 feet 9 inches over, and 22 feet clear between the paddle boxes. It is propelled by a pair of oscillating engines of 112 H.P., of which the cylinders are 42 inches in diameter, with a stroke of 3 feet, and it is steered by one rudder. The draught of water is 5 feet 6 inches. There are two lines of rails on the deck, with space for fifteen waggons. The vessel runs from six to seven double trips per day, and carries on an average 180 waggons, equal to 56,340 per annum. The rate for the carriage of minerals and other heavy goods is sevenpence per ton.

The cost of the works on the Tay was:—

	£.	s.	d.	£.	s.	d.
Slipways	2,600	0	0			
Platforms and Girders . . .	4,800	0	0			
Stationary Engines and Gearing	1,400	0	0			
				8,800	0	0
The 'Napier,' with Rails and Stores ready for Sea				9,182	0	0
Total Expenditure . . . £				17,982	0	0

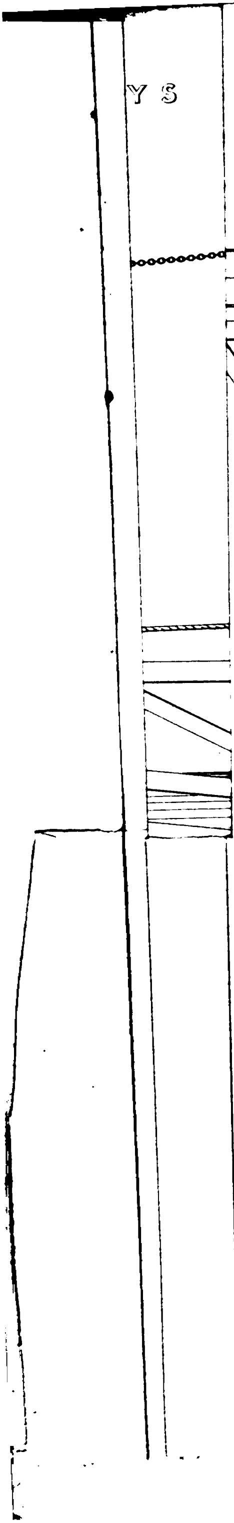
Great credit is due to Messrs. Anderson, the Contractors for working the ferries, who by their energy contributed much to the success of the undertaking. The Author has to express his thanks to Mr. John Paterson, of Edinburgh, and Mr. Robert Nicholson, of Burntisland, for furnishing him with particulars as to the cost and the recent working expenses. It may not be irrelevant to observe, that when this work was first projected by Mr. Bouch, and submitted to the Directors of the Company, the advice was sought of Mr. Bidder, the present President of the Institution. With a frank appreciation of the design, that eminent Engineer recommended, that its development should be left to Mr. Bouch, and the Author has the satisfaction to state, that the undertaking has fully and successfully effected the object required.

Although ten years have elapsed since the construction of the 'Floating Railway' now described, perhaps its originality and usefulness, and its importance as applicable to rivers and estuaries in this country, in India, and elsewhere, may render it not unacceptable to the Institution, and to the profession. Where the expense of a bridge, or of a tunnel would form an insurmountable objection to their construction, as at the Mersey and Bristol Channels, or where the navigation would not admit of interruption by the erection of a bridge, a similar work might be adopted with advantage. The increasing commercial intercourse between this country and France, point to the necessity for some such mode of communication across the Straits of Dover. The result would be, not only greater facilities for the transit of goods, but also means for the interchange of waggons. Then might be seen at different stations on the Continent, waggons labelled with the names of Manchester, London, &c., and corresponding ones inscribed Lyons, or Paris, on our English railways.

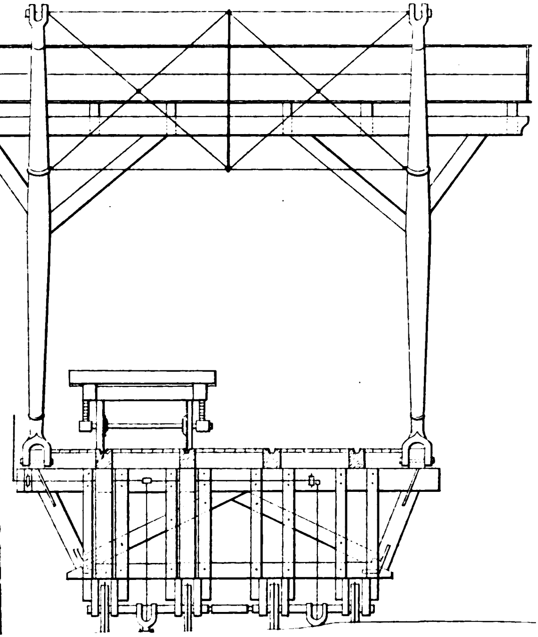
The Paper is illustrated by a series of diagrams, from which Plate 4, and the woodcut, (Fig. 1,) have been compiled.

[Mr. Bouch

PLATE 4. VOL. XX.



CROSS SECTION AT A.B.



Mr. Bouch said, it was only an act of justice towards the late Mr. Grainger, to state, that it was he who originated the idea of floating trains across the Forth, which object he proposed to effect, by using hydraulic cranes, as the means of transferring the waggons to the deck of the vessel. Mr. Bouch, however, considered, that the delay necessarily involved in the adoption of that plan, would render it practically unavailable, for the amount of traffic which crossed the ferry. He did not think, that the various operations of bringing the waggons within reach of the crane, then transferring them to the deck of the vessel and placing them in position, could be effected in less time than five minutes per waggon, or twelve waggons per hour. This would only allow of the passage of one hundred and forty-four waggons per day of twelve hours, assuming that the whole time was occupied in loading; but the time required for unloading, and for crossing the ferry must also be taken into account, so that the traffic which could be carried across the ferry must, necessarily, be very limited. With regard to the Tay Ferry, Mr. Grainger proposed a different plan; to throw out a long girder from the shore, resting upon a floating pontoon. Mr. Bouch thought favourably of that plan, but it could not be carried out at the time, on account of the expense. The size of the pontoon required, would be scarcely less than that of the vessel itself, perhaps, indeed, even larger; and the length of girder required for even a moderate inclination down to the vessel at low water, would be considerable. On the Forth he should not, from choice, have adopted so steep an inclination as 1 in 6; but the space where he was obliged to place the moveable platform, was so extremely limited, that he had no other resource; and it was for the same reason, that upon the Tay, the inclination was so much as 1 in 8. In a Bill for a ferry, in which he was interested, now before Parliament, the proposed inclination was 1 in 15. He thought, that with that slope, and with the class of vessels described in the Paper, aided by the experience already gained in working the existing ferries, both passengers and goods would be conveyed across, with the utmost regularity and ease. But whatever might be said in favour of a ferry of this kind, it fell far short, in convenience and facility, of a bridge, and the expense of working it was much greater than that of a railway; wherever, therefore, it was practicable, a bridge should be preferred. The contract for the Forth Ferry was let to Mr. Anderson for £3,200, or £3,300 per annum, and adding the interest upon the original cost, with 10 per cent. for depreciation, the actual cost of working the ferry would amount to nearly £6,000 per annum. Taking the number of trucks conveyed at sixty thousand, the cost of conveyance for each truck would be 2*s.*, and taking its load at an average of 2 tons, it would amount to 1*s.* per ton. It was evident, that this far exceeded the cost of transport on the railway, over the same distance.

Mr. BATEMAN claimed for himself, the original idea of crossing the Frith of Forth by means of a railway vessel. In 1845, whilst Engineer of the Edinburgh and Perth Railway, he proposed a similar plan for the passage at Queensferry; and he exhibited the drawings which he prepared in 1845, showing a locomotive on land, and a shallow vessel with ten carriages upon deck, together with the ferry approaches, at an inclination of 1 in 12. The whole train was to be lowered by the locomotive on to the deck, passing over tail-pieces, or gangways attached to the vessel, and the same plan was to be adopted on the other side of the ferry, where the carriages would be drawn up the inclined plane, one by one, by the locomotive. In 1846, he had shown these drawings to Mr. Grainger, and he thought it possible, that they might have suggested the idea of adopting this mode of crossing, which afterwards, in the hands of Mr. Bouch, had been successfully carried into actual execution. The Frith of Forth was only about three-quarters of a mile broad at Queensferry, and it was more sheltered there than between Granton and Burntisland.

Mr. GREAVES thought, that the ingenuity of the plan was principally displayed in the travelling platform. He had had some experience of the floating bridges mentioned in the Paper, where the whole operation of the transfer was effected from on board the vessel. The plan was introduced by the late Mr. Rendel, and the economy of that method of loading, unloading, and working was very great. The floating-bridge system, as it was called, had never been adapted to railways, or for the transport of railway carriages, but it had only been employed for the conveyance of foot passengers, animals, and ordinary vehicles. The passage was rapidly effected; for he recollected having seen a regiment of soldiers transported from one side of the ferry at Portsmouth, to the other, in five minutes, including the forming of the men on each side. In these floating bridges there were 'brows,' or tail-pieces, which were lowered for the passengers to embark and to go on shore. One of the floating bridges was established at the Hamoaze, where there was a current of 5 knots an hour. As the brows were carried on board, it was possible for the vessel to effect a landing at any point. In the plan under consideration, as the vessel was very closely guided to the rails, the travelling platform became an effectual substitute for the brows.

Mr. T. E. HARRISON observed, that for the last thirty years, there had been a ferry in uninterrupted operation across the Tyne, at Shields, in which the same plan had been adopted, with one exception. The inventor, the late Mr. Chapman, intended to have sunk a well for the counter-balance weight, which was to regulate the movement of the traverser; but as that plan could not be carried out, he made the balance weight traverse over a wheel at the top of a tower. The traverser was so nearly balanced, that a man by merely turning a handle, could regulate it with the greatest ease, as the tide rose and fell, to suit the vessel as it was brought up. The only real difference between this plan and the one described in the Paper was, that the first was employed for the transport of passengers, carriages, carts, and goods, and that the other was used for the purposes of a railway.

Mr. Bouch observed, that owing to the height from which the carriages had to be lowered, it would be difficult to make tail-pieces of sufficient length to answer the purpose. The draught of the vessel being about 5 feet, and the deck being also about 5 feet above the surface, gave a total of 10 feet, which would require a girder 120 feet in length, in order to be level. With so great a depth of water, in some places as much as 40 fathoms, and so great a width as five miles, the chain was inapplicable, and the trucks could not be lowered down an incline of 1 in 12, with the locomotive simply.

He wished distinctly to be understood as not having laid any claim to be the original inventor of this moveable platform, though when he first conceived the idea, he was not aware it had occurred to others. In the case of the Shields Ferry, the vessel was brought up broadside instead of end-on. He understood the plan had been successfully carried out in several places in America; and he found from conversation with Mr. Scott Russell, (M. Inst. C.E.,) that that gentleman entertained the idea of crossing the Thames in a similar manner, before the plan was adopted in the several instances which had been alluded to.

Mr. Vignoles thought nothing more invidious and more to be deprecated, than inquiries as to priority of invention. Inventions were matured from ideas, crudely in the first instance, but afterwards reflected upon, and, in the course of time, practically applied. As well might it be said, that the old Roman potters who stamped letters upon their clay, were the inventors of printing, as that any person who threw out a crude idea, which was afterwards matured, could lay claim to that particular invention. In 1838, when the discussion took place upon Mr. Rendel's Paper, "On the Floating Bridge across the Hamoaze from Devonport to Torpoint," Mr. Vignoles expressed himself in the following terms:—

"That the plan now proposed would obviate many difficulties which occurred in the case of railroads; there were many situations in which the floating bridge might be adopted with great service, and he could not refrain from expressing his admiration of the great forethought, skill, and design, which were here exhibited;

at the minuteness with which the details had been studied; and, not the least, the adaptation of the balance weights for the chains; the chains not having elongated, proved of itself how completely they answered their intended purpose."[1]

It was evident, that the idea was already matured, when Mr. Rendel completed his floating bridge over the Hamoaze; and he was glad to know, that it had been successfully applied to railways.

Mr. **Sheilds** inquired, whether any practical inconvenience was found to arise from the position of the connecting girder, which must be in a state of oscillation at one end, whilst it was fixed at the other.

Mr. W. **Hall** replied, that the universal joints enabled the girders to oscillate in every direction: and at the end of each girder, a hinged steel point was attached which rested on the rails of the deck, sliding with the movement of the vessel. Each girder was independent, turning upon its own hinge. No inconvenience had arisen from this cause, and he did not believe, that the waggons had ever left the rails. In this plan, there was no provision, or necessity for tail-pieces.

Mr. **Ormiston** had constructed a small steam ferry across the Medina, in the Isle of Wight, which was worked by chains, upon Mr. Rendel's system. Although, from the great width of the Frith of Forth, chains might be inapplicable, he thought they would have answered for the Tay, where the width was less, and where the distance was not much greater than at the Hamoaze. That system possessed this advantage; that in foggy weather, the vessel would be brought up, with certainty, to the landing place, instead of having to grope for it. He did not think it would be an improvement to lessen the inclination for the slip to 1 in 15, for a vessel with a draught of water of 5 feet, and a range of 2 feet, or 3 feet, would require a moving platform about 150 feet in length. He thought it would be preferable to apply more force to pull up the carriages, than to have such an unwieldy landing-platform.

Mr. **John Murray** remarked, that in the Frith of Tay, the force of the current which ran through the gorge, at Broughty Ferry, at the rate of 4 knots an hour, would render the use of chains impracticable. Although there was, at the Hamoaze, a current of 5 knots an hour, the place was more sheltered than the Tay. The ferry was established near the open sea, and was subject to a considerable lift.

Mr. J. **Cockburn Curtis** remarked, that in America there were usually ferry boats on each side, with sheltered recesses, or docks, for their reception; and he thought much of the success of the American ferries was owing to those provisions for rapid working and comfort.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. i. (1838), p. 23.

Mr. Bouch, in reply to a remark by the President,—that 10 per cent. was a small allowance for depreciation in steam-boats,—said, that the boilers constituted, in that respect, the chief source of expense. They were calculated to last about eight years, and it would cost about £4,000 to renew them. The cost stated in the Paper, included the whole expenses incurred by the railway company for the purpose of directing the traffic across the ferry. With regard to the proposed inclination of 1 in 15, the only change that would be required in the moveable platform, would be an increase in its length.

Mr. Greaves remarked, that in the question of cost, the larger works of the piers at Granton and Burntisland must be considered; those works afforded considerable shelter.

Mr. Bouch observed, that the storms came, principally, from the east, and the breakwater was not erected until two, or three years after the ferry was in operation. The Forth was much exposed at that point, where the ferry was established, yet during the two years of Mr. Anderson's contract, there was not a single day on which it was not worked. He had never known an instance of the carriages leaving the line; indeed, it was almost impossible that they should do so, because the girder was in the form of a trough, with the rails at the bottom; and the scotching of the carriages upon the deck, gave sufficient security.

Mr. Bidder,—President,—remarked, that an instance was now afforded, of the difficulty of maintaining a discussion upon strictly practical papers; all the information that was to be obtained upon the subject was soon exhausted. There could be no doubt of the success with which this plan had been carried out, and it was immaterial to know with whom it had originated. It was quite true, as had been stated, that a similar system had been in operation for thirty years on the Tyne; and at about the same period, the President was employed, under Mr. Palmer, in designing a ferry across the Thames which, however, was never executed. There was little merit in a simple conception of this kind, as compared with a work, practically carried out in all its details, and brought to perfection. With regard to the ferries upon the Forth and the Tay, it was, at one time, a question whether the principle of using chains, introduced by Mr. Rendel, should be applied. As to the Forth, where there was a width of four miles and a half, and a considerable sea to be encountered, with a strong tide to the east from the North Sea, chains were, evidently, inapplicable, and he doubted whether that plan would have answered for the Tay, although the width of the latter was only seven-eighths of a mile. Moreover, there was no proof, that the adoption of that plan would be attended with greater economy, and the service might often be subjected to irregularity by the breaking of the chain. It was, certainly, not capable of the speed which had been attained on the ferry of the Edinburgh, Perth, and Dundee Railway. The transit of the traffic was accomplished at a cost of one shilling per ton for four miles and a half, as contrasted with one penny, or three halfpence, where the railway communication was uninterrupted. He believed one shilling per ton would cover the cost; but he must take exception to the allowance of only 10 per cent. for depreciation. According to his own experience, the constructors of engines endeavoured to compress the boilers as much as possible. If he were building a steam-boat for himself, he should, after having settled the boiler space to the satisfaction of the builder, insist upon, at least, 50 per cent. more; he would thus incur additional expense in construction, but subsequent economy would be the result. The inadequacy of the boiler power was strikingly manifested, in the case of the screw colliers from the Thames to the North. The rapid wear and tear of the boilers, and the length of time the vessels were laid up for repairs, were large drawbacks upon the economy of those vessels.

April 23, 1861.

GEORGE PARKER BIDDER, President,
in the Chair.

No. 1,038.—"The National Defences."[1] By GEORGE PARKER BIDDER, Jun., M.A.[2]

THE object of this Paper is to bring under the consideration of the Institution of Civil Engineers, the National Defences of the Kingdom, and the means that have been and ought to be adopted, to provide for the safety of the country, in case of foreign invasion. The subject is one, the intricacy of which is only equalled by its importance. Intricacy, because from the changes which modern improvements have produced and are producing in the art of naval warfare, from the innumerable schemes and proposals which are continually put forward, both for the construction of ships and the fortification of the coast, from the singular variety of design exhibited in the productions of the naval authorities and from the want of clearly defined principles, the whole question has become involved and perplexing in the highest degree; and there can be no doubt of its importance, when its bearing on the political and commercial prosperity of the country and the enormous interests to be protected, are fully considered. It is, moreover, of peculiar importance, when the political aspect of the times and the general feeling of the nation alike demand, that the most energetic and effective measures should be taken, for placing the safety of the country beyond the reach of danger.

The expenditure in which the nation has been involved, on account of its defences, within the last ten years, is enormous, and calls for the most serious inquiry. It has been ascertained, that during eight years, from the commencement of the year 1853 to the beginning of the year 1861, the sum of £29,000,000 has been spent on the maintenance and reconstruction alone of the navy, exclusive of all items for pay, wages, dockyard improvements, &c. As for the reconstruction, the result has been, that during that period, as nearly as can be ascertained from the Navy List, vessels carrying about 3,006 guns have been launched, including gun-boats, besides a few packet-vessels, tenders, &c; and it is further found, that at the beginning of the period, there were on the stocks vessels carrying a total of 2,859 guns, and at its close, vessels carrying 976 guns. Now assuming roughly, that the vessels at each period were, on the average, half-finished, the result is, that the amount of shipping added to the navy, during that period, would be represented by 2,065 guns, and if the ships are valued at about £4,000 per gun, there is given the sum of about £8,000,000 to represent the value added to the navy in new ships. The remaining £21,000,000 must therefore be assumed to have been spent in the maintenance, equipment and conversion of ships, and in "miscellaneous expenditure," whatever that may be. Besides this, a sum of about £12,000,000 has been recently voted for the construction of various military defences along the coast;—a sum of itself sufficient to pay for the construction of a large fleet of first-class vessels.

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[1] The discussion upon this Paper extended over five evenings, but an abstract of the whole is given consecutively.

[2] The Author has since been elected an Assoc. Inst. C.E.

Surely when dealing with interests of such importance and sums of such magnitude, it is necessary that some fixed principles should be arrived at, and the whole question be placed on a more firm and satisfactory basis, than it has hitherto been, so that there may be a reasonable confidence that the money, so liberally provided by the nation, may not be uselessly as well as lavishly expended.

But before proceeding with this Paper the Author feels, that some apology is due to the Institution for the apparent presumption on his part, in introducing a subject on which he can have neither general experience, nor any peculiar knowledge. It is not, however, his purpose either to offer any opinions, or schemes of his own, or to dogmatise on those of others, but merely to attempt so to arrange the subject and to introduce to the notice of the Institution the really important questions on which it depends, as to facilitate its discussion.

Considering the great importance of the question and the growing conviction, that the vast sums of money voted by the country, for the construction and maintenance of the navy, have not been prudently, or effectually expended, and that the coast defences at present contemplated, or erecting, at such enormous cost, are many of them unadvisable and of little, or no apparent practical value; considering also the fact, that from the nature of the public service, that competition and conflict of intellect, so essential to the development and perfection of art and science, find little, or no place in the design and execution of the Government works of this country, the Author has been induced to submit the present Paper, in the belief, that the subject comes peculiarly within the province of the profession, that a discussion upon it among the Members and visitors would be of great service to the country in general, and that the conclusions might possibly react upon the public departments to which it applies.

The first great question which proposes itself for consideration, at the outset of the subject, is this:—There are two modes of defending the country,—the one by the navy and the other by coast defences,—and the primary point for consideration is, whether the navy alone should be trusted to, and the energies of the country be devoted to the task of rendering it of such a character and strength as will insure to Great Britain the mastery of the seas, especially of the home seas, against any combination of foreign powers; or whether a part of the resources of the nation should be employed in providing a supplementary protection to the shores, by means of fortifications, to any and to what extent. Now it is clear, that any decision on this, and indeed on every other question involved in the subject, must be materially influenced by the consideration of the peculiar advantages and disadvanges arising from the position and resources of the country.

The insular position of Great Britain renders it liable to an invasion from an enemy, at almost innumerable points, which it is manifestly impossible can all be protected by any system of land fortifications; but any such invasion must be attempted by an enemy having ample means of transport, as well as ports convenient for the purpose of embarking an invading army, with its stores and munitions of war. This induces the inquiry where such ports exist, and upon examination they will be found to be extremely limited in number; on the French coast, Cherbourg, Brest, and L'Orient, are all that can be counted as fit for the purpose, and beyond these there are not any others between the Cattegat and the coast of Portugal, except Flushing;—while Russia has not any harbour nearer than the Baltic, and even if combined with France, the Russian fleet would have to force a passage through the Straits of Dover, or to sail round the whole island, before it could combine with that of France. The ports of embarkation, being thus limited, are accordingly easy of observation, and it follows, that so long as the English fleet retains the command of the Channel it would be impossible, without gross negligence, for any invading expedition to put to sea. Such an expedition must involve the collection, at two, or three ports, of an enormous number of transports and a large fleet, for the purpose of convoy, and could not possibly be organised in secret.

Moreover the substitution of steam ships, for sailing vessels, introduces new points into the consideration of the question. It increases the rapidity and certainty with which troops can be transported and landed, but at the same time it gives increased facility for watching, or blockading the enemy's ports and for conveying intelligence of any threatened expedition, and it also augments the efficiency of a marine force, in protecting any given extent of coast. So long, therefore, as England can meet her enemies upon the seas, and can maintain her superiority there, the advantages accompanying the use of steam power are on her side; but if that supremacy be lost, and the protection of the country be made to depend on the coast defences, the advantage of steam power is entirely upon the side of the invader.

The insular position and the consequent extensive seaboard, which causes the anxious contemplation of the possibility of invasion, affords at the same time some superior advantages, which do not appear to have been sufficiently considered and appreciated, in the organisation of the navy and of the coast defences. Looking at the seaboard throughout its whole extent, it will be seen, that there is scarcely any point, without some adjacent port, or harbour, capable of being rendered fit, at a moderate cost, for the reception of vessels of war for the purposes of replenishing their stores and ammunition.

Besides this the whole coast is, or will be connected, by the railway system, with every part of the country, within which there exists an exhaustless store of coal and iron; whilst in the manufactories and ironworks, there is a power capable of producing and supplying the munitions of war to any extent. By these means, and at the shortest notice, the Government would be enabled to provide and convey to any of these harbours an unlimited supply of coal, of ammunition, and of the material for naval warfare generally. Thus, then, there exists a base for naval operations in the home seas, comprising not only the Government dockyards and arsenals, but the whole extent of seaboard and the entire mineral and mechanical resources of the country. The importance of this fact and the influence it ought to have, on the decision as to the best means of defending the country from invasion and of preserving the national supremacy in the Channel, cannot well be overrated, and the advantages it confers, over other maritime countries, is enormous.

It is clear, that in future warfare, a base of operations must be provided for a fleet, as formerly for an army, and the naval base must rest on an ample supply of coal. When, therefore, the subject is regarded from this point of view, the superiority of this country, for operations in the Channel, over that of any foreign country, becomes manifest.

Bearing in mind these considerations, the question recurs, whether reliance should be placed solely on the fleet, or whether it ought to be supplemented by land fortifications, to any and to what extent? This also involves the consideration, of whether the maintenance of the national supremacy in the home seas, is an object of paramount importance to the country? and on this there cannot be any hesitation in replying in the affirmative. The main strength of Great Britain lies in her enormous mineral resources and numerous harbours. The chief strength of the power, from which alone invasion may be feared, lies in its enormous army. So long, then, as the British fleet is unconquered in the Channel, England would, in the event of war, meet that, or any other power, on the most favourable terms, and would have the benefit of all the natural advantages before alluded to. In fact, in a good steam fleet there is interposed a barrier, which must be swept away, before an invading expedition could be despatched with any reasonable hope of success.

Such an enterprise as an invasion would seem hopeless, in the face of a quick, vigilant, and powerful fleet continually hovering about the enemy's ports; but if that fleet were worsted, the enemy would have all the advantage of his superior military power and organisation, and the military forces would have to meet him at any point he might select on the coast, an event which, unless well provided for, would probably be attended with the most disastrous consequences. That contingency, however, could doubtless be provided for, to some extent. Improvements in the coast line of railways would enable stores and troops to be rapidly assembled at any threatened spot; the movements of the regular troops could be covered by the Volunteer force, whilst simultaneously, the labouring power of the country could be employed in throwing up earthworks, destroying roads and bridges, and in impeding the advance of the invading force. In this, the services of the Members of this Institution could be conspicuously useful.

As to whether it is prudent to apply part of the national resources to the erection of land fortifications, a few remarks may be made, before leaving the question for the discussion of the Institution. Any attempt to protect the shores generally, by such means, must be hopeless, on the score of expense alone; the question, therefore, reduces itself to the advisability of fortifying the dockyards and arsenals, and possibly some two, or three points, palpably open to invasion. The estimates show, that this cannot be effected, except at an enormous cost, and the military authorities state, that the forts, when erected, would require a very large number of troops to man them. If the same amount of money were employed in the construction of additional ships of war, would not the end be answered quite as effectually, while at the same time the Channel fleet would be only properly augmented? It should be borne in mind, also, that an attack on the arsenals can scarcely be contemplated, so long as the Channel fleet remains intact.

It may here be suggested, whether it would not be prudent to still further develop the advantages which the country affords for naval operations, by the formation of additional harbours, on different parts of the coast, for receiving and rapidly supplying ships with coals and other stores.

Assuming, then, that it is considered essential to render the Channel fleet as strong and as effective as possible, what description of ship should there be built for that purpose? This most important question involves several minor considerations, in the discussion of which, it is necessary to bear in mind the changes which the modern improvements in gunnery and in the application of steam power to propulsion, have produced.

The weight and destructiveness of the guns and projectiles have been greatly increased, and where 24 and 32-pounder guns were formerly used, there are now 68-pounders and 10-inch guns. The range and accuracy of these rifled cannon are much greater than formerly, whilst the size and destructiveness of the missiles now used, and the certainty with which shells may be exploded at any distance, have rendered the effect of individual shots much more important than formerly.

The introduction of steam power has produced equally great changes, by enabling vessels to be propelled with a certainty and speed hitherto unattainable; but at the same time, the increased calibre of the guns and the weight of the engines, coals and necessary stores, have added to the load to be carried by ships of war, to an extent, which the experience of the last few years has shown them to be totally inadequate to sustain; in fact the best and newest timber-built ships, after a comparatively short period of service, become leaky and unseaworthy.

In considering this part of the subject, it is submitted, that the vessels of war should be adapted to utilise and to develop, as much as possible, the peculiar resources of the country, that is to say, the coals and iron possessed in such abundance, and the facilities for supplying ships, whenever required. They should also be adapted to economise, as far as possible, the actual supply of effective seamen. They should be designed to achieve the greatest speed, consistent with effectiveness in other respects, by giving them finer lines and greater length, by which a velocity might be attained which it is hopeless to attempt, with the heavy bluff bows hitherto adopted. The objection that vessels with fine lines cannot carry bow guns, seems of little weight, when it is considered, that a ship having an increased speed of 2 or 3 knots might, when chasing, proceed at such an angle to her course, as to bring her whole broadside to bear, and still to make good the same ground in pursuit, as she would have done previously by steering in a direct course. The increase in efficiency may be said to be directly as the increase in speed, and a superiority in that respect, in the case of a vessel engaged with another of greater power, or with several ships, would be invaluable.

It is also of importance to inquire what material should be used in the construction of ships for the future navy. Long usage has established wood as the material for building ships of war, and although iron has been so largely adopted in the mercantile service, it is asserted to have been found unfitted for naval purposes. The question however has become a very important one, because, as was before noticed, the wooden frames of the present vessels have been found entirely inadequate to support the additional weight imposed on them. Moreover the increasing scarcity of wood, suitable for ship-building purposes, is a well-known fact, and at present the dockyards are to a certain extent dependent on foreign countries, for timber of the best quality. On the other hand there exists an inexhaustible supply of iron at home, as well as the skilled labour for producing iron ships to any extent.

Some of the principal objections to the use of iron are stated to be its liability to splinter when struck by shot, and the difficulty of stopping the shot holes, as also the constant fouling of the bottoms of iron ships.

As to the first objection it may be remarked, that the destructive effects of both shot and shell are now of much greater importance than the secondary effects produced by splinters, and it may be doubted whether these latter will be found to be so serious as formerly, on account of the greater velocity and momentum of the shot, which tend rather to punch out, than to tear the iron. There are on the other hand many advantages in the use of iron; such as the greater strength attainable, the comparatively little repair and renovation required, and the freedom from danger of injury, or loss by fire. These are questions peculiarly fitted for discussion at the Institution.

The next point which arises, is the now much-vexed question of fortification of ships of war, by means of iron plates; how far it is advisable and in what manner it should be applied. Upon this point very many and contradictory arguments have been advanced. There is no doubt of the terrific effect which modern artillery would produce upon vessels built after the old fashion; the enormous bolts would carry everything before them, and the molten iron and 'Armstrong' shells, though with less power of penetration, would scatter destruction on every side. That is a strong reason for protecting war-vessels with iron plates if possible. On the other hand it is known, that a thickness of iron of at least 5 inches is required to resist completely, the heavier description of shot. It is clear, that such a defensive armour would involve an immense addition to the weight of a ship, and must greatly impair her efficiency in other respects.

There are already two notable examples of what can be done in this respect;—the French vessel 'La Gloire' and the English ship 'Warrior.' Of the 'Gloire' though scarcely any exact information has been obtained, it is known that she is provided with such a thickness of plate as to render her almost impregnable, that she has been tried successfully in heavy weather, and that she has proved to be faster than is usual with vessels of war, and doubtless she has been built on finer lines. As to her construction, it is said that she has a wooden frame upon which are fastened the iron armour plates: it may be thought that this is an arrangement open to many defects, but still there seems little doubt that the 'Gloire' is a successful and a very formidable vessel. The 'Warrior,' as is well known, although much longer, is but partially fortified, having her extremities unprotected. Lord Clarence Paget has assured the House of Commons that this is to render her more seaworthy. Now it seems evident, that this necessity of leaving a portion of the vessel unprotected, if it be a necessity, is a great imperfection in the system of fortification, as these unprotected ends would naturally attract an enemy's fire, and they would probably cause the disabling, or even the loss of the ship. It is said, that this is provided for by a system of bulkheads, with arrangements for admitting water to any part, to restore equilibrium. That may be so, to a certain extent, but it cannot be doubted, that the vessel would be much more efficient in all respects, if she were fortified throughout, and also that if both, or either of the extremities became waterlogged, the vessel would be rendered much less navigable. It becomes a question whether this imperfection is necessary. With the example of the 'Gloire,' this seems more than doubtful. It is not denied, that although plated throughout, she is a fast vessel and a good sea boat; it is clear, therefore, that the 'Warrior,' if she had been constructed on the same proportions, with plates throughout of the same thickness, would have proved both a faster and a more seaworthy vessel than the 'Gloire,' on account of her greater size. One point in the construction of the 'Warrior' may be noticed, in which it seems questionable whether a great reduction in the weight might not be made, without impairing her efficiency. The guns are principally on the gun deck, and over that is a very heavy and massive spar deck, on which also a few guns are to be placed. The bulwarks on the spar deck are comparatively slight, low, and undefended by plates, and are apparently very insufficient for the protection of the men stationed there. It is suggested, whether the entire removal of this spar deck, thereby converting the present gun deck into the spar deck, would not lighten the vessel, so far as to admit of the extremities being plated uniformly with the sides, and whether it would in any way impair the efficiency of the vessel. The guns would then be worked entirely from the spar deck, and free from the obstruction of the smoke. The latter alone is an important consideration, because it is well known how seriously the smoke, hanging about a ship, interferes with the working and aiming of between-deck guns, whereas accuracy of aim is now of more importance than it has hitherto been. The bulwarks also might be made sufficiently high and staunch to afford considerable protection to the men on deck.[1]

In such a ship, it is contended, that the spars and rigging should be of a very subordinate description, and therefore it is not requisite, as in a sailing ship, to have a clear deck for working the sails. But on this subject of fortification it may be argued, whether too much is not attempted in desiring to make vessels completely ball-proof. Whether in so doing their efficiency is not to some extent sacrificed, and whether on the whole it would not be practicable to produce a more formidable fleet, by adopting the system of protective armour on a more moderate scale, which though inadequate to resist entirely heavy solid shot, at short distances, would protect the vessels from shells and shot fired from long ranges. By so doing, lighter and faster vessels, and more of them, could be built for the same amount of money. The question appears to be, not merely how to achieve perfect safety, but what thickness of defensive armour will give the maximum of general efficiency.

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[1] In an account of the "Trial Trip of the Warrior," which appeared in 'The Times,' Saturday, September 21, 1861, it was stated, that "the 'Warrior' made her first real sea-going trip on Thursday last [September 19], in a voyage from Greenhithe to Portsmouth." She was said to have answered her helm like a yacht, and to have made her way through the water faster than most quick sea-going mail steamers. She averaged a depth of 25 feet 11 inches; namely, 25 feet 9 inches forward, and 26 feet 3 inches aft. The engines at first were only allowed to make from 34 to 36 revolutions, subsequently increased to 40 revolutions, when passing from fresh to salt water. Off Sheerness, the 'Warrior' saluted the flag of Admiral Johnstone with 15 guns from her battery of (solid) 68-pounders (of 95 cwt. each). "The shock of each gun was sharp and sudden, but less than half of what is felt on such occasions in wooden ships, no matter what their size. Of smoke on the main-deck there was really scarcely any; the small ports kept it out instead of in, and when the salute was over the main-deck was almost entirely free, while the open deck was wrapped in a dense cloud." The course was along the Harwich side of the river, and the speed of the engines was gradually increased "from 40 to 48 revolutions, the steam, which had been kept as low as 15 lbs., was got up to 20 lbs., and with this, at three-fourths' speed, the 'Warrior' bowled along through a sea like glass at a rate of rather over 13 knots, or 14½ miles an hour." From this trial it is judged that her speed at the measured mile, with the engines making 58 instead of 48 revolutions, will be 14½ knots, or not less than 16 statute miles an hour. On Friday morning the 'Warrior' "stood in towards Spithead, and made a short turn round the harbour to choose her berth, and saluted the admiral's flag with fifteen guns. There was a slight breeze blowing at the time, and the smoke from this salute on the main-deck was scarcely perceptible, even to sight. At a little before 8 o'clock the anchor was let go, and the 'Warrior' thus accomplished her first voyage, of 220 miles, (including all her slow speed in the river, three-quarters speed at sea, stoppages and delays in the offing), in rather less than 20 hours, or at the average rate of 11 knots an hour."—EDITOR.

Another point may be noticed, bearing on the present question. From the great accuracy and range now attained, it may be anticipated that, in future, naval engagements will be, at least partially, fought at much greater distances than formerly, and that it will not be possible for ships to come alongside and batter each other by the hour, as in the days of Nelson. Now a little consideration will show, that at long ranges the height of a target is more important than its breadth, so that a low target is much more difficult to hit, than a target of the same area, but with greater height. This fact clearly points to the propriety of reducing ships to single decks, and making them as low in the water as is consistent with their seaworthiness and efficiency in other respects. By these means, also, the strain upon the framework of the vessel would be much diminished. Vessels of this description would doubtless carry a smaller number of guns, than vessels having two, or three decks, but they would also be less expensive in construction, and might therefore be more numerous. Possibly this also may be considered an advantage, and that the enormous cost and large number of men required for a three-decker is too much to venture in one vessel, in these days when almost a single shot from the heavy guns now used, or a collision with a ram might send the whole to the bottom. In future naval warfare it is probable, that a number of comparatively small, very fast, low, scantily-rigged, and heavily-armed vessels, will be used for Channel service, which, when at sea, will cruize in pairs, and which, from their superior speed, will be enabled to engage with vessels of much larger size, on advantageous terms.

Another main point to notice is the rigging of vessels intended for service in the Channel.

There is no doubt that ships of war will, for the future, depend chiefly on steam for their motive power. Now there is an abundance of coal always within easy reach of vessels on the home stations, and numerous harbours at which to ship it; there is no need therefore either to carry large stores of coal, or to economise it by using the sails, as in the case of vessels on foreign stations. On the contrary, a far greater economy would be effected in an article of which there is very great need, namely seamen, by fitting out the vessels with spars and rigging of the lightest description, so that scarcely any more men would be required, than those necessary for working the guns and the engines; thus also by these means the ships would be very considerably lightened, and there would be less danger of fouling the screw, by the wreck of spars in an engagement.

As to the description of guns to be carried, it seems undeniable, that a broadside of heavy guns would be more destructive, than a broadside of smaller artillery, throwing the same aggregate weight of shot; it may therefore be asked, whether this principle ought not to be carried as far as the mechanical resources, in the manufacture of large guns, and the strength of the vessel will allow; whether, in fact, the armament should not consist entirely of the heaviest guns that can be constructed?

If the foregoing considerations are correct, it is submitted, that they indicate, as the proper description of vessels to be employed for Channel service, iron vessels built of great length, with fine lines and great power, to insure speed, and carrying an armament of very heavy guns on the spar deck alone,—that they should lie as low in the water as is consistent with safety, and be protected by iron plates of moderate thickness throughout their whole length,—and that they should be fitted with spars and rigging of the lightest description.

Another and totally distinct question relates to the practicability and advisability of constructing 'Steam Rams;' at present they may be said to exist only in theory, as it has been decided, that the 'Warrior,' which was at first supposed to be intended for a 'ram,' is to be used only as a steam frigate, nor is the 'Gloire,' with the exception of her sharp receding cutwater, especially adapted for this purpose.

It can hardly be doubted, that the effect of a 'ram' properly constructed, and of sufficient size and speed, among a hostile fleet, especially a fleet of transports, both in destroying and demoralising an enemy, would be terrific. It seems clear, that a ram, to be effective, must be of greater size and weight than the largest man-of-war afloat, and be capable of attaining the highest rate of speed.

It is submitted also, that any attempt to combine the qualities of a ram with those of a fighting ship would only impair its effectiveness; besides it must be considered, that the service would be attended with more than usual danger, and therefore it would seem right, that the crew should be limited to the smallest number by which the vessel could be worked.

The observations already made, with reference to the impropriety of heavily rigging ships-of-war, apply with double force to the case of steam rams, because anything beyond the lightest description of rigging would be certain to go by the board, at the first shock, and would very probably foul the screw. From the strength and thickness of the frame and the requisite size, there is no doubt, that the expense attending the construction would be very great, too much, it may be argued, to risk on such dangerous service; but then it must be remembered, that the destructive effect on the enemy is also proportionately great, and that it would pay the country to construct these rams, even with the certainty of their being destroyed, if they could insure the previous destruction, by their means, of some three, or four of the enemy's ships. With these remarks the question is left to the Institution, whether on the whole it is advisable to build steam rams to assist in the defence of the country against invasion?

Having looked thus far at the subject of the building of ships, attention must be turned to what is the best mode of dealing with the present navy, and of converting the old men-of-war into efficient ships. The usual way in which the old ships have been dealt with, has been to lengthen them some 30 or 40 feet, and then to put in powerful engines and an armament of heavy guns of about the same number as before, and to rig them as sailing-ships; the result is similar to that already noticed as appearing in the case of the modern screw liners. The frame of the vessel, which was quite sufficient to sustain the comparatively light armament of twenty, or thirty years ago, is inadequate to support the increase of weight, and the ship is consequently soon rendered unseaworthy. It is suggested, whether it would not be a wiser course to cut down these vessels, so as to have all the guns on one deck,—the spar deck,—and to dispense with the heavy spars and rigging. This would reduce the weight of the vessel sufficiently to compensate for the addition of engines, and might probably also admit of the fortification of the sides; while by bringing the vessel higher out of the water it would give a finer line of floatation. By this means also the strain on the vessel would be diminished, and a more efficient ship, it is submitted, would be produced.

It must be noticed, that the subject of this Paper being the National Defences, the observations on ships have been exclusively confined to those intended for service in the seas surrounding the shores of the British Isles, and are therefore not necessarily applicable to the case of vessels required for foreign stations, where the peculiarities and requisites of the service are so widely different.

In conclusion, the Author craves the indulgence of the Institution for the imperfections and incompleteness of the Paper. The vastness and complexity of the subject render it impossible, even were he competent, to discuss it properly within such circumscribed limits. He has therefore confined himself entirely to the task of arranging the subject for discussion, and of indicating, so far as he is able, those questions and principles which he conceives to be most important for consideration, whilst he has abstained, as much as possible, from intruding any opinions of his own.

[Mr. Bidder,

Mr. Bidder,—President,—thought the subjects treated of in the Paper were of such importance and interest, that it was desirable to endeavour to indicate what, in his opinion, should be the course of the discussion.

It was perhaps desirable, first to account for the apparent anomaly of the introduction of a purely military subject for discussion before a Society of civilians. The reason was, that all the recent ameliorations in the manufacture of artillery and small arms, showed that warfare itself was rapidly becoming a question of mechanical power. The mystery in which the construction of forts, ships, and artillery had hitherto been shrouded, was being rapidly dispelled, and in fact was now brought completely within the range of ordinary mechanical discussion. Indeed, in looking at the discussions which took place in a more august assembly, as well as in other places, it was evident, that the question was one which could only be satisfactorily argued where general mechanical subjects were habitually discussed. There were other scientific Institutions which took up particular branches; but this discussion embraced all the branches of the engineering profession: and the President must contend that at this time, when such enormous sums were being devoted to the National Defences,—a subject which occupied the attention of almost every intelligent mind in the country,—the Members of the Institution could not dispose of their time, as citizens and mechanicians, more beneficially and instructively, than in the discussion of the questions embraced in the Paper.

He was the more inclined to take this view from what was now occurring. As he had before stated, the construction of the ships of the navy, the building of forts, and the manufacture of artillery, had hitherto been considered as a sort of secret craft, not to be pried into by profane eyes. It was a craft which depended a great deal upon technical terms: but when he looked into certain Blue Books that had been published,—when he recalled the discussion upon artillery that took place before the Institution, during the last year,[1]—when he looked at the forts which had been constructed and were now being built along the coast, he was bound to say, that he was not impressed with deep veneration for the authorities, which heretofore had been, and to a great extent were still, employed upon those works. The Blue Book, lately published, containing the "Report of the Commissioners appointed to inquire into the Control and Management of Her Majesty's Naval Yards," developed the principle by which the Admiralty had been guided, in ordering the construction of new ships and in altering old ones, and it must be evident to all those who had given attention to the subject, that one of the greatest wants in that department was scientific and practical knowledge. The forts at Plymouth and at Sconce Point, and other places, as well as others now in progress, were evidence of this want of scientific knowledge, and of the want of appreciation of the powers of modern artillery. Therefore, as President of this Institution, and as a citizen of this country, he felt that no justification was required for bringing this great and important subject under the consideration of the meeting.

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[1] *Vide* Minutes of Proceedings, Inst. C. E. vol. xix., p. 338, *et seq.*

In the Blue Book to which he had alluded[1] there was a statement, which appeared incomprehensible: at the same time there were a few figures to which he would direct attention. Appendix No. 27 seemed to be published with the view of answering the speech of Lord Clarence Paget, in which he attacked the late Comptroller of the Navy. Now the President defied any one to understand that Appendix, from which it appeared that in the eleven years, from 1848 to 1859, the whole sum of money expended in building, repairing, and reconstructing the ships of the British Navy was £12,000,000 of which £5,000,000 were said to have been appropriated to the building and the reconstruction of ships: while the total tonnage of the British Navy was probably about 1,600,000 tons. What had become of the £12,000,000, in addition to that voted for the improvement of the British Navy he could not say; but that these figures were wholly delusive, he had no doubt whatever: and when it was reported, by a Committee of the House of Commons, that in no one of Her Majesty's Dockyards had there been a system of accounts adopted, by which the cost of any vessel, or other work, could be ascertained, the public would not be surprised at the results arrived at. Now he need not tell the Members of the Institution, that there was not any extensive firm in this country, conducting the operations of ship-building, engine-building, or any other great manufacture, that could save themselves from bankruptcy, unless they kept a cost-ledger, in which every outlay was registered and tested with the net receipts: and to his knowledge, in some of the largest concerns in this country, doing business to the amount of £300,000, £400,000, and £500,000 a-year, the difference of amount would not be £1,000 a-year; and indeed it depended upon such a system, whether they made a profit, or went headlong to ruin. Therefore he need scarcely say, that when a number of large public establishments, like the Royal Dockyards, were conducted upon a system by which the cost of the particular works could not be ascertained, a state of circumstances existed involving the greatest national risk. It was to be regretted, that the Committee to which he had alluded, and which appeared to have done its duty very fairly, had not associated with it some men of mechanical experience. If such had been the case, it was clear from the evidence, that they would have been able to detect the real sources of waste in the naval establishments of this country.

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[1] *Vide* "Report of the Commissioners appointed to inquire into the Control and Management of Her Majesty's Naval Yards, &c. Folio. London, 1861." Appendix No. 27 B, page 519.

Returning to the suggestions in the Paper, the great question to be discussed was, whether it was absolutely necessary for this country to have the command of the Channel? If England had not supremacy in the Channel, which as stated in the Paper was the best and indeed the only highway for an invasion, what was the use of the whole coast bristling with forts? The whole coast might be rendered apparently impregnable; but if the command of the Channel was not maintained, all source of national glory and prosperity would be gone; and a national disgrace would be incurred, which this country could scarcely appreciate. If on the other hand the Channel was held, what was the use of the forts? If England possessed the best fleet and the fastest vessels, what could be the use of the forts? The question then to be discussed was, Whether the fleet should not be master of the Channel, and if so, what was the description of fleet which ought to be organised for that object? With regard to that, as the Paper stated, not only for the Channel, but for all other services, the primary consideration was, what was the moving power which a fleet must possess, in order to attack this country? Now that power was Coal; and then came the question of the arrangements for the supply of that resource. As regarded the other side of the Channel, nearly all the harbours were of such a character, that no large fleet could concentrate, except at Cherbourg and at Brest. As to Cherbourg there was this observation to be made,—if the English fleet was master of the Channel, Cherbourg would not be a place where a fleet could concentrate. It was admitted by all practical men in this country, that if the fleet was master of the Channel it would be also master of Cherbourg: and if it were master of Cherbourg, what was the use of Alderney? because if the French ships could destroy the English fleet, they could also destroy Alderney. It was true, that the late Duke of Wellington considered the fortification of Alderney to be a matter of great importance; but with all due deference to so high an authority, it must be remembered, that his opinion was given under circumstances which did not now apply. It would be almost as reasonable, to quote the opinion of William the Conqueror upon warfare with bows and arrows as against artillery. The case with regard to Cherbourg was very different, when the Navy consisted exclusively of sailing vessels, firing only round shot from their guns: but now with a steam navy and rifled artillery, Alderney was entirely superseded. Being masters of the Channel, the fleet did not want a harbour there, and if the supremacy in the Channel were lost, an enemy could destroy everything that took refuge in the harbour of Alderney.

But then came the question of supplying the coast with harbours of refuge. The east coast was most deficient in that respect, and it was a fair point for discussion, where those harbours should be constructed, and of what description they should be?

The Paper then raised the question of the vessels themselves; chiefly with respect to the speed to be attained, as that was a point of the utmost importance. The question was, whether a vessel having a speed of 15 knots an hour was not equal to two vessels of 10 knots an hour? He did not mean 15 knots an hour upon trial in smooth water; because all persons, practically acquainted with the subject, knew that the speed of a vessel was what could be attained, with head to wind; and the speed of a vessel having the bluff bows of most of the men-of-war, was more materially reduced in a head sea, than one with sharp clipper build. It was therefore most important to ascertain, to what extent it was practicable, consistent with efficiency in other respects, to give speed to the vessels of the fleet. Then there was the question of masts and yards. There were very sufficient reasons for giving full rigging to vessels intended for long voyages; but for Channel service, it was a subject for grave consideration; as in actual warfare, spars and sails were rarely required, especially for a fleet of steam vessels, which scarcely ever had a fair wind. It must also be remembered, that a vessel going 15 knots an hour, even in a calm day, made a strong breeze, and the top hamper of spars and rigging would, under such circumstances, take half a knot per hour from her speed. Now in the case of the 'Warrior,' the weight of her masts, rigging, and sails was about 180 tons, which was an important item, even as dead weight, when speed was required; but when resistance and risk, in case of engagement, were considered, the question became much more serious. That was a subject which should be fully and fairly discussed.

With regard to plating vessels with iron, for resisting shot, the question should be considered under three heads.—First, to what extent this protection should be given, in vessels for Channel service. —Secondly, to what extent it should be given, in vessels for moderately distant service, such as the Mediterranean, where the enemy would probably be encountered near his own quarters,—and Thirdly, as regarded more distant stations, and the British colonies. It might be contended, that it would be good economy to have separate classes of vessels, especially adapted for each of these services. Perhaps also it might be a subject for discussion,—though it was almost a foregone conclusion,—whether vessels with more than one gun deck should now be constructed. Vessels with two and three decks were mere charnel-houses; they required an immense number of men to work them, and any one who had gone over a man-of-war in commission, could not fail to have noticed a large number of men of a class that it was not desirable to have brought into the service. The Royal Navy should consist only of picked men; the service ought to be one of promotion, and in order to the efficient manning of the ships, there should be a well-selected body of men, better paid and better cared for than in any other service in the world. But that was impossible, so long as the fleet contained great hulking men-of-war of 100 and 120 guns, which only went to sea to come back into dock for repairs. Besides, it was generally admitted, that a heavily armed gun-boat going 2, or 3 knots an hour faster than these huge tubs, would be quite a match for any one of them. Under these circumstances, it was a fair subject for discussion, whether that large and cumbrous class of vessels should not be altogether abolished?

Then came the question, which apparently had never been fairly discussed anywhere:—In what way the future Navy of this country should be constructed and maintained? The conclusions of the Commissioners, as given in the Blue Book, were such as would not induce any great degree of confidence in the authorities at the Admiralty. No doubt a great cloud had been thrown over private contracting, by the mistakes that were made in constructing the gun-boats, during the Russian war. But with all its numerous faults, there was one great satisfaction attending the system,—that with all the errors (and scarcely one practical man ever expected they would turn out sound vessels),—the circumstances under which the vessels were contracted for, were of that character, that it was unreasonable, if not impossible, to expect that they would turn out sound wholesome vessels. Still there was this satisfaction,—that the public could know to whom the fault should be attributed, and it was possible to trace who built the vessels, and if the fraudulent builder could not be punished, he could be held up to the bar of public opinion and reprehension, which could not be done in the case of ships built in the Government Dockyards. When a Dockyard-built ship turned out unsatisfactory, it was not possible to ascertain who was to blame for it: but when it was contracted for by a private builder, and more especially if it was constructed of iron, no defect, of any great extent could exist, without its being possible to trace its author; and if a financial remedy could not be obtained, a moral remedy could be achieved.

There was another question, upon which the Paper had not touched, but which ought not to be overlooked in this discussion; —it was, what had been done, with a view of ascertaining the best kind of artillery for all uses? A lengthened and most exciting discussion had taken place upon this subject, during the last year, and the President then ventured to suggest, that there might be a combination between the systems of the two great names,—Whitworth and Armstrong,—which, he still contended, would result in some combination which should command the confidence of the country. At that time it was distinctly understood, that the challenge which was given by Mr. Whitworth, for the guns being tried in a manner to put their respective powers fully to the test, should be accepted and acted upon; but this had never yet been done. Sir William Armstrong had achieved a great success with his gun in action; but that was not the whole question. The question for the country was, which was actually the best gun? because any gun was bad, if there was a better. In war, the most effective engine was that which was most likely to insure success: and this country, which spared no expense, ought to be assured that the most effective weapon had been secured for its service. The competitive trial had never been made, and the President must say, that the fault appeared to rest entirely with the Ordnance Select Committee; he had seen the terms of the trial which were sent by the Committee to Mr. Whitworth, and which, it must be admitted, were all made with a view of bringing into favourable contrast the powers of the Armstrong, as against the Whitworth gun. That might have been all right, although it did not appear so to indifferent persons. Mr. Whitworth did not object to it, but he proposed to have other and more severe tests: and the result was that the trial was never made.

The President trusted, that the discussion would not conclude, without some information being communicated as to the further experience which had been attained in the perfection of artillery: and although last year he had refrained from expressing his own opinion of which was the best gun, he should not now shrink from the expression of his opinion on that subject, which, with all the other points, would, he hoped, be very fully and freely discussed.

Mr. G. P. Bidder, jun., said, he felt it was necessary to apologise, for having brought before the meeting a subject upon which he could have no claim to be heard on account of any special knowledge of his own. At the same time it was a subject of the greatest importance, which had been considered by everybody, had been canvassed in the public press, and debated in the House of Commons; he therefore thought it ought to be brought under the notice of the Institution of Civil Engineers, as the best place in which to discuss it freely, thoroughly, and efficiently, and as no one else had brought it forward, he had ventured to do so. He had endeavoured to confine himself to arranging the subject, and to developing it, in a form adapted for discussion. If he had done more and had introduced opinions of his own, they would of course be taken for what they were worth. His purpose was to bring the subject under general consideration. He thought it should, as far as possible, be dealt with upon general grounds, because it was of so extended a character and its ramifications were so wide, that if the speakers entered into details, it would be impossible, in a discussion of any ordinary length, to arrive at valuable results. What was required, was to have fixed principles to govern future operations, rather than to enter into questions of detail; in fact it was useless to go into details until some general principles were arrived at, to guide the practical operations; therefore he thought the subject should be viewed entirely in a comprehensive and general light, and he ventured to express the hope, that the Paper and the discussion might be productive of beneficial results.

Colonel Adair confessed he was unprepared, at this early stage of the discussion, to be brought so prominently before a body of gentlemen so competent to detect any errors in reasoning, and to correct those errors when they appeared. It would be unbecoming on his part, not to admit that he had given some attention to this subject, according to the opportunities afforded by recent improvements, especially with reference to the defence of this country, by works of construction and by artillery; and he might add, that, having served for some considerable period of time on the spot, respecting which so much discussion had originated,—he meant the great arsenal of Portsmouth,—he had had the advantage of such experience as was afforded by the daily movements of the Royal Navy, at that harbour. Therefore he might be permitted, though with very great diffidence, to make some remarks upon a subject which he was happy to see had attracted the attention of the great body whom he addressed, as it had that of the Author of the Paper, who, though young in years, and also in his connection with the Institution, gave the better hope and promise, that the youth of England would give their scientific attention, no less than their physical strength and energy, to the maintenance of the just supremacy of their native country by land and sea. And he might be allowed to add in the language of the poet:—[1]

"Bold, firm, and graceful, are thy generous youth,
By hardship sinewed, and by danger fired,
Scattering the nations where they go; and first
Or on the tented plain, or stormy seas."

He was struck with the subdivision, which the President had introduced, as regarded the Royal Navy;—into the Channel fleet, that fleet which would be more immediately brought into collision with an enemy, possessing the same arms of precision as their own;—and the fleet designed for service in the great distant colonies of the Empire.

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[1] *Vide* "Thomson's Seasons."—Summer.

The introduction of direct shell fire, inaugurated by General Paixhans in 1822, had rendered an iron hull a necessity for all vessels destined to be engaged in future European warfare. This induced the consideration of the defensive equipment of these vessels, of which the President had spoken. In the first place, a doubt occurred, whether the authorities had not been rather hasty in deciding, that a determinate, ponderous, equipment was equally essential, for the floating battery,—for the vessels designed to range in the first line of battle and to meet adversaries of corresponding defensive armament,—and for those destined for lighter service. And on this point, another doubt arose. The majority of those present were probably familiar with the physical circumstances of Spithead, which formed the outer harbour, or roadstead of the great arsenal of Portsmouth. It was of a remarkable character, inasmuch as the entrance was one of singular difficulty, considering the necessity of sending forth, and of receiving very large vessels.

He would thus explain the conditions on which he based his inference, that it was not requisite to arm, even vessels for the European line of battle, as heavily as seemed to be the idea in some quarters.

Suppose an isosceles triangle; whereof the base A B = 3,500 yards; and the sides A C, B C = 2,300 yards. The sea base A B stretched from 'A,' Fort Monkton, on the west, across Spithead to 'B,' Southsea Castle, and the apex 'C' represented the Blockhouse Fort, at the throat of the passage into the inner harbour. The fairway from the Solent ran outside the sea base to a point rather to the S.E. of Southsea Castle, where it turned to join the in-shore channel at an obtuse angle.

He had been for some time in command of Southsea Castle, where the armament was very formidable, and whence, during practice, he had seen two thousand rounds, of shot and shell of various descriptions, fired from the ramparts. Now he never permitted a gun to be laid, until he had previously carefully ascertained whether any shipping was coming in, by the angle of approach he had spoken of, to the straight in-shore channel, into the harbour, and he could confidently say, that he scarcely ever, during a long period, saw a vessel come into such a position that he could have made an effective shot, if she had been protected by an iron coating.

This led him to another point. When the angle of impact from a 32-pounder gun, at a moderate distance, against oak timber, was reduced to 15°, the shot would glance; much more then if the shot was fired against an iron-plated vessel. If therefore, in the entrance to one of the great harbours, it rarely occurred that a vessel approached, except for a short period of time, at a considerable angle, to the batteries commanding the entrance; it followed, that although it was necessary to protect a vessel against shells, it was not requisite to have such heavy armour as would disable her for sea-going operations. For this and similar considerations, he believed that it was not requisite to encumber a vessel to so great extent, with heavy plate armour, because it would seldom happen, especially with the aid of even limited screw power, that it would be compelled to remain, for any considerable time, in such a position, as that the plane of impact would be perpendicular, or nearly so to the line of fire. In the experiments against iron plates, shot had been fired at short ranges, with heavy guns, under circumstances the most favourable to the guns. The target was moored and was all but immoveable. The plane of impact on the first trials was vertical, and the plane of fire formed a right angle to the vertical plane, consequently there was neither the deflection which the momentum of a vessel's course insured, either horizontally, or vertically. But still an idea had arisen, that it was desirable to ascertain what power of deflection existed; and it was now understood, that with vertical plates placed at an angle of 35° or 40° the success in deflecting shot was very complete. Therefore it appeared, that in discussing the question, it should be considered, whether they might not dispense,—except for floating batteries,—with the heavy iron plates of 4½ inches and 5 inches thickness, which were spoken of.

Then as to the qualities of the iron itself; he should ask for information from gentlemen familiar with the texture and composition of that metal. He had observed, that there was considerable difference in the tenacity and texture of different qualities of iron. He found that extended to all proportions of the ores in combination, in different metals, and in an eminent degree to those metals deposited by electro-galvanic agency, as distinguished from those in a laminated state, from rolling. It might be a question whether iron 'swaged' up under a steam hammer, was as capable of resistance as iron submitted to the action of a powerful system of rollers, at all events he apprehended there was a difference in the crystalline texture of the metal produced under the two systems of manipulation. He was led to this idea, from seeing the changes in the texture of iron when worked at high velocities, as in the case of railways. It might then be inquired, whether as yet, the best and toughest texture of iron, for the purposes of the defensive armament of the ships of war, had been obtained.

Next with regard to Steam Rams. He confessed he had very little faith in that mode of attack. It seemed to him to be a very expensive mode of attaining an end, which might be worked out more satisfactorily by other means. The object was offensive and destructive impact upon the mass submitted to the blow. Putting out of view the questions arising out of the incidents of collision on railways, he would ask, whether there had not been cases where the steam power employed for propulsion had not produced too great vibration, for the cohesion of large masses of inert matter. Vessels had returned to port disabled from the mere racking, caused by the weight of their armament. If this were correct, he thought the steam ram might be projected with such violence as to produce one of two effects,—either to displace and to set in motion the masses to the rear of the motive forces; or from the construction which was necessary, the impact might tear out the main portion of the fabric, on which constructional strength depended. Even if this disruption did not occur, and the steam ram was powerful enough to overcome all resistance, still it might be, that an equally effectual result could be attained by the use of heavy projectiles from an ordinary plated ship, without recurrence to the same expensive mode of strengthening such masses as must be employed in the case suggested.

He now ventured in the presence of officers who had experience where he only had theory,—who had applied practice where he only had had the opportunity of looking on,—who were prompt to correct a fault where they observed it,—in their presence, he ventured to say a few words with regard to the land defences of England.

There was no doubt, that the main strength of England was on the sea:—that it was the bounden duty of the Legislature to develop to the highest possible extent, and to give the greatest expansion, to the operations of the navy: but it had been found in former times, that the expectations, apparently justly founded, as to the efficiency of that navy, in regard to blockade, had proved delusive. Commanders, whose intelligence and activity were never surpassed, had lost, in consequence of a gale of wind, a fleet blockaded in a French harbour. Nelson himself missed the track of the French fleet, time after time, and it was to avoid the possibility, the consequences of the recurrence of such a contingency, that he advocated the alternative system of National Defences, which he believed might be provided, at a cost not worthy of consideration in an economical point of view; and this by the fortification of the sea coast, in certain positions. In the first place, the Channel fleet could maintain the narrow seas as an undoubted possession and highway: but that fleet must, in that case, be devoted especially to that purpose: and then, unless there was a fleet which should sweep the narrow seas and guard them also, there must be some shore defences, on several parts of the island: for if so great a calamity ever occurred, as the attempted invasion of England, it would not be a solitary enterprise, hazarded wherever a landing could be effected, but it must be a general and simultaneous combination, to attack several points of the island simultaneously. It must not be understood, that he desired to divert the great energy of England from the arts of peace, to the pursuits of war; but in order to remain at peace, it must be shown that the nation was prepared for war, both as regarded the navy and the coast defences.

Then as to the system of fortification to be adopted. The Meeting would be aware, that a system of fortifications had been largely developed. Taking the most important point first:—the great arsenal and fortress of Portsmouth. An inspection of the new works constructed there would be interesting to any scientific Engineer. There was now a construction to the westward of Gosport, between Fort Gomer, and Fort Elson, consisting of five forts, of which four were elaborately planned and detailed, on the polygonal system, now most in favour on the Continent. The system on which the works were formed was, to construct the most important portions of the line of defence, in the first instance, and to arm them very heavily. The garrison was thus left in this advantageous position, that if an enemy approached and they were weak in their numbers to resist and to give battle in the field, it was easy to link together the main works, in themselves capable of substantial defence, by such lines, or earthworks as were needed. Such was the nature of the works on the Gosport side. If, on the other hand, the garrison was strong, there was the opportunity of selecting a line of battle on their own ground, and of manœuvring in the intervals, as might be thought fit. Such works, he believed, were essential to the protection of that arsenal, and considering the nature of the ground over which the operations extended and the enormous range of projectiles, he thought that the question of expense ought not to be regarded, in order to provide the means of keeping an enemy at a distance from one of the greatest centres of the nation's maritime strength. It might appear scarcely credible, that with rifled ordnance a bolt could be projected from the shore at the root of Ryde Pier into the dockyard at Portsmouth! Such were the results of the terrible artillery that could be brought to bear in the present day, and therefore it was necessary to adopt a system, which would give that arsenal adequate means of defence. It was not intended to construct continuous works, such as the lines which existed, round Gosport and Portsmouth, but to prepare points of resistance, whence to check an enemy's further advance. What was said of one dockyard might be said of all. They were points which were being fortified upon the best construction known in modern times; and if the expense was unusually great, as it doubtless would appear to be, it must be remembered, that the object contended for was the maintenance of the domestic security of the country, and for that any expense, however great, must be incurred. Mistakes and errors of judgment there might have been: but he did not hesitate to affirm, that the only observation that was made upon these works, by foreign Engineers, was that they were too strong.

With regard to the floating batteries, it appeared that there was great difference of opinion as to their use, for the defence of Spithead. It had been proposed to establish upon four, or five of the shoals, tier batteries, upon the principle of those which so long kept the fleet from the head of the Baltic, at Cronstadt. Colonel Adair's opinion was, that floating batteries, heavily plated with iron, should be employed at Spithead; and he remembered a circumstance, which showed how unfavourable to general defence the position of those forts might become. He had been absent from Southsea Castle on duty, and returned at about midnight on a very dark night, and knowing that there were men-of-war lying between the Castle and the Isle of Wight, he endeavoured to descry them, but was unable. It then struck him, that these forts, which were marks by day, as respected the shoals on which they rose, might serve also as beacons by night, since there would be the sharp outline upon the sky, as seen from the low level of the sea, and vessels might run in and take up their position alongside the forts, unseen from the batteries on shore.

He had paid considerable attention to what had been said with regard to the artillery now in use. He was not aware whether it was generally known, that a most formidable smooth-bore gun had been cast for the coast defences of the United States. The American Engineers had given much attention to coast defences, as they evidently regarded the Atlantic seaboard as the prominent point of attack, and they prepared accordingly. Shells were now habitually projected from 10-inch guns, and 11-inch guns were introduced generally in the United States navy. In a work published by Major Barnard, U. S. Engineers, a 15-inch gun was described, the practice with which gun was given; as also the charges of powder and the weights of the projectiles. The difficulty hitherto had been, in casting these heavy guns, to secure homogeneous and sound metal. This difficulty had apparently been overcome in the case of the 15-inch gun by an invention of Lieutenant Rodman. The gun was cast with a core, and the metal was solidified in the interior, by the introduction of a stream of water, so as to insure the greater solidity of the metal in the vicinity of the charge. The gun was stated to be 15 feet 10 inches in length: its weight was 22 tons 18 cwt. 44 lbs.; the thickness behind the chamber was 25 inches, and the diameter at the muzzle was 25 inches. It was capable of throwing hollow projectiles of the weight of 305 lbs.

and of 410 lbs.; and two kinds of shell were employed, of those weights respectively. There was an objection, on the part of the inventor, to the employment of round shot, on account of the greater weight and size, "for reasons already mentioned connected with solid castings of large masses." Therefore he divided the projectiles into two classes of shells, which might be called the shell of explosion, used against troops and earthworks, and the battery shell, employed against works of construction. It was stated, that the initial velocity of the projectiles was very great, and that they could be fired with charges of powder up to 40 lbs. or 50 lbs.; the 40-lbs. charge being the coarse, or ordinary common powder, and the 50-lbs. charge of Rodman's perforated cake powder, being powder compressed, in order to retard combustion, and thus to cause the least amount of strain upon the gun. The cake was perforated from point to point, to allow the passage of the flame into the interior of the charge. This gun, it was stated, could be loaded and run into battery in one minute ten seconds, being worked by a sergeant and six men. A gun throwing such a projectile must be considered to be a formidable addition to coast defences. Now if the forts were armed, and the arsenals were strengthened, although the important places of attack were less exposed to risk, the points at which an enemy might make any future inroads became more clearly indicated. Hence the country had the opportunity of preparing defensive earthworks, in which the skill of the Engineer would be called into action, in the prospect, or event of foreign invasion. And here he was sure that he should have the sympathy of the Institution, when he alluded to the valuable services which their body might render in the preparation of such means of defence. Indeed, he could not look upon the great body of Civil Engineers, who had done so much at home and abroad, in bridging over large rivers and estuaries, in driving tunnels through the hearts of mountains, and in leading the iron ways over the surface of the country, than as a corps of great talent, available and ready, if their country required their assistance, and he hoped they would form a corps and place it at the service of Government.

It was evident, that as the points of defence were multiplied, as the arsenals were formed into fortresses, capable of substantive defence, so the interior of the country must be guarded, and he would also affirm,—notwithstanding the mode in which the question had been, for the present, postponed, to more pressing subjects,—that a well-considered and deliberate defence of this great Metropolis must be provided for. He did not wish to direct attention to any exaggerated results of the undisciplined efforts of patriotism; it was admitted, that the bravest and most resolute men, without organisation, were not able to do that duty in the field, to which their courage prompted them: and unless scientific means were devised to assist them, even the discipline of the field would be useless. He threw out this subject for discussion, in order that his views with regard to the Metropolis might be either confirmed, or disproved. He was convinced of the truth of his position; and whilst they saw probable revolution and almost certain war brooding over the face of the Continent, it was their duty, as reasonable and discreet men, to make due provision for the defence of this island, in every quarter; not counting the cost, but looking only to the safety of the country itself. And he would further state his deliberate opinion, that regard being had to the circumstances of ground, to the spirit of the people, and to the power of organisation, there was no capital in Europe better adapted for a legitimate defence than London, and its environs.

Mr. J. Scott Russell expressed a doubt, whether he could say much that was new on the subject, or that would add anything material to the very comprehensive suggestions which had been made in the Paper. There were, perhaps, a few technical points into which he might enter, more fully than it was possible to do in the Paper; and there were also one, or two points in the opening address of the President, upon which he would make some observations, confirming some of the views and, with great deference, contesting others; the latter being perhaps the point of view which would be most congenial to the President's wishes, as contributing to the utility and interest of the discussion.

Mr. Russell then proceeded, at considerable length, to observe, that although there were many points on which, in common with others, he was well inclined to find fault with the Admiralty, the War Office, and other departments, yet it was more agreeable to concur with their acts, and this he could conscientiously do, as far as regarded some of the recent appointments, which he conceived were calculated to conduce to the benefit of the several services, and the general advantage of the country.

Mr. Bidder,—President,—would apologise for interrupting Mr. Russell; he submitted that it was scarcely the province of the Institution to discuss the political constitution, or the official appointments of the Board of Admiralty, or of the War Office, but rather to consider the result of their proceedings.

Mr. Scott Russell stated his readiness to abandon that part of the subject; but he conceived that he was only following up the line of argument which the President had initiated.

Mr. Bidder,—President,—begged to differ from that position; he judged of each department solely from its works, and not from its political construction.

Mr. J. Scott Russell said he would withdraw any political remark into which he had been unintentionally led; although he confessed he was at a loss to discover the political tendency of the observations he had made. He would therefore proceed at once to the question of the mechanical construction of the 'Warrior;' and would commence with the manner in which she had been designed.

The 'Warrior' was an instance of a ship being constructed in a manner which should be generally approved by Engineers. The history of the 'Warrior' was simply, that in 1855, a vessel of that type was considered by Sir Baldwin Walker to be desirable, and models and drawings of it were carefully prepared for his consideration. Sir Baldwin Walker thus convinced himself, that a vessel of the 'Warrior' class,—although of smaller dimensions,—ought at once to have been built by the Admiralty; but he was convinced, that it was as much as his position was worth, to venture, at that time, to ask the Board of Admiralty to undertake a series of investigations into the subject. In 1858, the French had gone a little ahead of England, in these matters; and in consequence, the Admiralty did exactly what all right-thinking men would have desired them to do, under such circumstances,—they set their own most scientific men to work upon the subject, and imported some scientific civilians into their council; and thus at the end of the year the design of the 'Warrior' was matured. Then the Admiralty took a step, for which the Board deserved the greatest credit. Although they were satisfied with the good qualities of their own design, and with the good counsel they had taken from Civil Engineers, yet they thought it their duty to take the advice of the whole profession, and see whether they could not gain from them some further information. They then consulted the six firms which were probably at the head of the profession, asked their advice, and took their designs; and it was not until that evidence and the designs had been before the Board, for a considerable time, that the final design for the 'Warrior' was decided upon.

Now Mr. Russell conceived, that a more liberal, or wider view could not have been taken by any department. There were several gentlemen present whose designs had been considered and of whose talent the Admiralty had taken advantage, and they were rewarded by receiving permission to send in tenders for the construction of this new class of vessel;—such was briefly the history of the origin of the 'Warrior.'

Now as to the construction of the 'Warrior.' He had very recently the privilege of examining that ship, and he must say, that a more admirable type of all the good qualities, which a construction of that nature ought to have, he had very rarely seen. The 'Warrior' was built by the 'Thames Ship Building Company,' a firm who were Mr. Russell's rivals in trade, and therefore he might be permitted to give his opinion freely, and he had the greatest pleasure in bearing his humble testimony to their excellent construction of the Admiralty design.

The 'Warrior' possessed several remarkable combinations of qualities; and he ventured to prophesy, that with Penn's excellent engines, the 'Warrior' would have a speed of full 14 knots an hour, in sailing trim, and then she would be at least 2 knots an hour faster than the 'Gloire.' The next points of consequence were the buoyancy and the great stability of the ship. The point which was generally urged against her was one, which in the nature of things, it was difficult to decide upon in such a construction. The 'Warrior' was severely criticised, because some parts of her hull were weaker than others; in other words, because the extremely fine extremities of the 'Warrior' were not covered with the same thick plates as were used on the middle, or waist. Now,—not with regard to strength,—(because the ship could carry any weight that could be put upon her,)—but with regard to sea-going qualities and to affording a stable platform for the guns, which was all-important,—he should not wish to add to the top sides of the 'Warrior' materially more weight than that which she now carried. He would desire to see a larger vessel than the 'Warrior,' and then with the same stability and the same good sea-going qualities as the 'Warrior,' a ship could be built, which would be able to carry armour plates over the whole length of her battery. He thought that this was an expedient kind of vessel to build, and he agreed that it would be a more expensive structure; but although she might cost more money she would really be cheaper, because she would carry more guns. Still, taking the 'Warrior' as she was, as a combination of good sea-going qualities of speed, and of stability of platform, he believed her to be a better vessel, in every respect, than any ship that had existed heretofore. Many naval architects might say, that they could suggest a great many improvements. This was probable, and in the next vessel those improvements might be adopted. It was still a great thing to have built one vessel, which was probably the finest that had ever yet been built. The 'Warrior,' as she stood, was just this;—she was an example of what the scientific constructors of the Admiralty could do, when they were not interfered with, and when they were permitted to have the advantage of the practical advice of Civilian Engineers and Shipbuilders, who had been engaged in constructions of that kind.

Proceeding now to notice the succeeding ships, the 'Black Prince' was merely a copy of the 'Warrior.' The 'Resistance' and the 'Defence' were very different kinds of structures, and with regard to them he was sorry to say, that the conduct of the Admiralty appeared to be without excuse. They possessed in the 'Warrior' and the 'Black Prince,' large vessels with stable platforms, having good sea-going qualities, and capable of making long voyages. Now what did they do? Instead of copying those ships, they proposed to make four new iron vessels, which were designed somewhat after this fashion. Let it be supposed that the Lords of the Admiralty and the Scientific Constructors met in consultation on opposite sides of the table. My Lords said, the Board had resolved upon having two more iron-plated vessels constructed, and they requested the Constructors to state their proposals, as to the nature of those vessels. The Constructors replied, that, "As far as they knew individually and according to the general opinion out of doors, the 'Warrior' and the 'Black Prince' were excellent vessels, therefore if their Lordships determined upon having more iron-plated vessels, it would be the wisest plan to copy those vessels." Their Lordships replied, that they could not consent to that proposition,—they had not got the money, and they inquired whether, as they had only got money enough for one more 'Warrior,' it was not possible to build two ships for that amount. "Certainly; if you wish it," was the reply of the Constructors, "but they will be slow vessels." To this their Lordships objected, and insisted that they should be fast vessels. These would evidently cost more money in proportion per gun, but their Lordships could not stand that, and the Constructors were urged to build them at the same cost per gun; therefore the Constructors were ordered to design two vessels, upon the same principle as the 'Warrior,' but which should only cost half the money of that vessel. Then there occurred a change in the Board of Admiralty, and two more vessels were ordered to be built; and still the bad luck which had attended the previous designs attended the new orders, and two new vessels were built more in discordance with the principles of science, and still more to the disapprobation of every scientific man, in and out of the service.

It was interesting to consider, what were the difficulties of this construction, and how it was, that the results had been the production of bad vessels. The difficulty was this,—that it was impossible for a scientific construction to combine in any form, and on any scale but one, the qualities which constituted a good ship of this nature.

The first quality, essential to a running-down vessel was speed; and it was admitted, that the vessels of this second class were about 4 knots an hour slower than those of the first class. But unluckily the slower class was that which had been chosen and fitted for running-down purposes! The first requisite of such vessels, was, he repeated, great speed. Now speed without size, was an element that no human science could create. Speed inevitably demanded length, and in these vessels speed without length was demanded.

Then every ship of that class must have a certain height of ports out of the water, in order to meet the ordinary contingencies of a sea-going vessel. Now the height of the ports out of the water had been fixed at 8 or 9 feet, and this could not be attained with small vessels.

The next point required was a stable gun-platform. In other words, the ship must not only have ends long enough to make her fast, but she must have a middle body long enough to carry her battery; not merely having a sufficient height of battery out of the water, but carrying it upon a stable platform. Now it was of no use telling the Constructors to build a ship, with a protected battery of that height out of the water, without adequate size. It was impossible to have that height of port, unless the vessel was of a certain length and breadth, to give that stability; and therefore it was absurd to attempt to produce shot-proof iron ships of only moderate length, with anything like adequate speed. It was unnecessary, amongst professional men, to enter into any arguments upon this question, and all would recognise the indispensability of that element.

Good sea-going vessels should also be able to carry coal enough for a respectably long distance. Now the 'Warrior' would carry coal for something like 1,500 miles of steaming, on her ordinary draught of water; but she had power to carry, at 2 feet more draught of water, an extra supply of 1,000 tons of coal, and therefore she had the capacity for carrying enough coal for 3,000 or 3,500 miles under steam. But what was the position of the 'Resistance' and the 'Defence?' Those vessels had, it was stated, a speed not exceeding 11 knots an hour. At that rate of steaming they would not carry more coals than would suffice for a voyage of three days. England had property to be protected all round the world, and if these shot-proof steamers were to be fought on all seas, it could not be done with such ships as these. Now take the 'Gloire;' imagine her to be chased by all four of these steamers that could only make 11 knots an hour and carry fuel for three, or four days. She had only to run away, and tempt them to follow, till they had consumed their coal, and then where would they be?

The next point, which had been much debated, and on which the President was understood to have very decided views, meriting careful consideration, was why should iron shot-proof steamers carry all the spars and rigging of a sailing ship? That was a serious question. The reasons why they should carry masts and sails were, because their opponents' vessels carried them, and because British ships would have to follow their opponents wherever they went, and because there was a vast amount of British property afloat all over the world, particularly between Australia and England. Now a British gold-ship was a very tempting prize for the enemy; it was therefore quite plain, that when the next war broke out, steamers of the largest size, of the greatest power, of the most formidable armament, and capable of carrying coal for 5,000 miles at least, and to act in all weathers, with every advantage both of machinery and sails, would be indispensable.

It was objected, that such vessels were not required for coast defences. Now Mr. Russell was considering the question of colonial defences. He contended, that these much-decried vessels were not built for any other purpose than defence; but he would also contend, that the best mode of defence was attack. And the British mode of attack had always been to seek for, to find, to follow, and to catch the enemy; not to stop till the enemy came to attack the fleet at Spithead! It was something new to be told, that the place to receive an enemy was at home! It had always been the custom of the British Navy to seek the enemy in his own ports. That was still the only safeguard: and Mr. Russell's belief was, that so soon as any foreign power had so large an armament, as to render it more expensive for this country to wait for him at home, than to meet him elsewhere, the fleet should go and seek and find that armament and put it out of harm's way, before it had done England any actual mischief.

Another point of material importance was, the question of draught of water, and upon this a great deal had been said. That was a difficulty which began at home. If the fleet remained to defend the shores of Great Britain, a very inferior class of vessel only could be used, on account of the small draught of water; but if, instead of staying at home, the mode of defence was by demolishing the enemy's fleet, in his own ports, then a superior class of vessel must be employed.

There were still a few points remaining, and on these it was important to obtain information. He must contend, that the Admiralty had committed a serious crime, for which it must give an account to this Institution. It was for having pretended, for the last five years, to make a series of experiments upon iron plates, and for not having made any one series of experiments, that could be of the slightest practical value. Now he believed the reason why a good series of experiments had not only not been made, but had never been permitted to be made, was this. It was understood, that there were four gentlemen in the Admiralty who advocated the building of iron ships. These gentlemen, in fact, compelled the building of such iron vessels as were in the service, whilst the whole of the remainder of the Board of Admiralty were decidedly opposed to it. What had been the consequence? Why that this latter section of the Board had been constantly engaged in making experiments, to show how good iron ships could not be built: and to prove that the advocates of iron were in the wrong. Therefore the experiments had been for the object of breaking iron plates, which were wished to be broken, and which, moreover, were intended to be broken.

An official denial was given to this.

However it so happened that the results gave a colour to such a supposition, and therefore it became most desirable that an opportunity should be afforded for an absolute contradiction to that statement. No one would be more delighted than Mr. Russell to receive an absolute contradiction by facts. Nevertheless he was obliged to state, that he was informed, that the experiments upon the 'Trusty,' which were the most trustworthy experiments that had ever been submitted to the public, were intended not to be successful. Perhaps however they would eventually prove to be so. He was under the impression that arrangements were made for their not succeeding; indeed it was understood, that written instructions were given, which, if they had been followed, would have induced the utter failure of the plates on the 'Trusty;' but somebody obliterated a few lines of the instructions, and instead of arrangements being made for the 'Trusty' not having fair play, "by mistake," arrangements were made that she should have fair play: and unluckily for them the 'Trusty' was put in a good position to resist the fire, and "by mistake" she did resist it. He hoped to receive an official contradiction upon this point, because if it was a mere rumour, it was a pity that it should ever have got abroad.

To put this right, it would be well to consider what honest men, wishing to make the best of the Kinburn experience in favour of iron plates, would have done. The French did this, and if there had been an honest and earnest desire to go ahead, and to promote the construction of shot-proof ships, the moment the affair at Kinburn was over, two of these floating batteries should have been brought out, and they should have been made to fire at each other, under the various contingent positions of actual warfare, by which means the Admiralty would immediately have ascertained all the effects of shot and shell of every description, and at every angle, upon these iron plates. The Government had been entreated to try these experiments promptly, and at length, apparently wearied by reiterated requests, a vessel was ordered to be hauled out, and another was appointed to fire upon her, when without further notice, or reason, the whole of the proceedings were arrested, by desiring that the experiments should be postponed; now that, in an official sense, meant:—"Do not make any experiments, and do not give us information."—"We don't want to know." That seemed rather an awkward fact, for the official gentleman who had denied the truth of the previous statements, and Mr. Russell hoped that he would be able to give another version of the affair.

It was essential to be well assured what quality of iron plates was best able to resist the impact of shot. Very little if anything correct was known about the effect of shot upon various thicknesses of metal;—nor of the effect of the impact of shot upon different thicknesses of plate, at different angles;—nor of the effect produced upon plates superposed, at various distances from one another;—nor as to what was the best mode of attaching iron plates together, so that they should add to the strength of the ship, and at the same time resist the shot. Mr. Russell was convinced, that if Civil Engineers had been commissioned to carry out honestly a proposition of this kind, they would at once have instituted a rational, comprehensive, and practical series of experiments, such as he had pointed out. All Engineers would have adopted some such course, and 'somebody' was to blame for the fact of its being possible, now about six, or eight years after the introduction of floating batteries, to complain that these all-important questions were points on which the Admiralty had left not only the profession, but themselves also, in a lamentable state of ignorance. If he was not in fear of censure for diverging into politics, Mr. Russell would say, that he believed this to be the work of the political part of the Admiralty; but he would correct his phraseology and say, that it was not done by the scientific department of the Admiralty.

There was one other point in which, he thought, great errors had been committed; and if he closed his remarks, without referring to it, the President might well censure him for having fallen into error. It was a great error to attempt to build all vessels to do everything: and it would be a good practical suggestion, that along with some ships, intended to go everywhere and to do everything, there should be constructed another class of ships, intended to go only to certain localities, to do specific things, and to be kept for that specific duty only. Now a class of vessels could be devised and constructed, having special qualifications for definite duties. For instance, there might be what he would call vessels of the sixth class, in which great speed should be combined with the capability for carrying heavy ordnance, and in which that speed and that armament would be without protection, except the partial protection which such vessels might have, when engaged end on in attacking a fort. That would be a very light and very fast ship, having a comparatively small number of guns. Then there should be vessels of a size and quality immediately above, (to be called the fifth class,) in which speed should be combined with what might be called 'vital protection,'—which meant, that the engines and boilers were protected from shot; but the men would have little more protection, than was at present afforded in wooden ships. Then there might be a fourth class of vessel in which speed was combined, not only with 'vital protection,' but also with protection to the gunners at all the guns. Then came the part of the question which was very difficult, as it was nearly impossible to know what degree of protection to give. The Admiralty had not allowed the world to know what degree of protection would be secured by plates of 1 inch, or 2 inches, or 3 inches, differently put together; and therefore it was not in Mr. Russell's power to say what degree of protection could be given to any part of any ship. One thing, however, the Admiralty had divulged,—perhaps against their will,—that 4½-inch plates were a protection against anything.

If a higher class of vessel was devised, a greater speed would be attained with protection for vessels and men, as in the 'Warrior,' and the 'Black Prince.' In vessels of above 7,000 tons it was practicable to obtain high speed, lateral protection, and an admirably stable gun-platform; in fact, a good sea-going vessel capable of steaming 5,000 miles, and fit to go anywhere and to do anything. This constituted the second class. If the size was extended to 10,000 tons, the vessel could have a completely protected battery upon two decks; this would approach the ordinary 100-gun ship, which might be called a first-class ship.

It was absurd to attempt to combine, in all these vessels, all their several qualities. It would be found that size must go along with and even govern every attempt to combine all these qualities, in one vessel. Under no circumstances was it expedient to build very slow vessels, nor to construct bad sea-going vessels, and for this reason. If an enemy having good sea-going vessels came to Spithead, where there were stationed heavily-armed, but slow-steaming ships, who could beat them off, but were incapable of following them, the money expended, in making that slow class of vessels, would have been wasted; whereas the expenditure of a little more money would have given the vessels the power of following an enemy and of safely attacking him at sea.

It was fervently to be desired, that the Admiralty would institute a complete series of experiments, to ascertain what, in every size of vessel, was the combination of material, by means of which would be obtained a certain degree of protection, with a certain amount of strength: so that a definite purpose could be accomplished with that certainty which a scientific and systematic course of practical experiments and a methodical experience could alone supply.

Mr. Bidder,—President,—said, he believed Colonel Jervois had been engaged upon some experiments upon iron plates, and the Members would be glad to hear his remarks upon that subject.

Lieutenant-Colonel Jervois, R.E., would at present only say, that experiments were now in progress, with the object of ascertaining the particular points to which Mr. Scott Russell had alluded. He would, with permission, postpone any observations he had to make upon the general question, until a later period in the discussion.

Mr. **Bidder**,—President,—had understood, that some experiments had been made, upon a combination of iron and stone, for embrasures. He should be glad to hear the result.

Colonel **Jervois** replied, the experiments which had been made upon embrasures, constructed of iron bars 10 inches in width laid horizontally upon each other, with flanges connecting them together, had shown that such an arrangement of material was practically invulnerable.

The effect of shot upon stone varied according to circumstances. If fired at for a length of time, the stone-work would be brought down; but if fired at, only for a given number of hours, it would stand sufficiently for all practical purposes.

Commander **Robert Scott**, R.N., wished to explain, (as far as his information enabled him,) the much-talked-of results of the firing at the 'Trusty.'

Captain Halsted had stated, that on account of the shrinkage of her wooden sides, the plates were not close against the timbers; and this Commander Scott considered, accounted for the absence of the usual splitting and curling up of the plates, on the impact of the shot. After the firing, however, it was observed, that the bolts fastening those plates, which were hit, had been pushed inwards; and it was then found, that the plates themselves had been driven home to the side of the vessel; thus clearly showing, that a considerable amount of the force of the blows had been expended, or absorbed, in the motion given to the plates. At Shoeburyness, however, where the plates were bolted tightly against the section of a wooden ship's side, they were either split, or curled up, at the ends, by being hit near the centre; and on a continuance of the firing, the plates were almost invariably broken up. In fact, if the different conditions were carefully considered, in a comparison of the effects produced, by the firing at Portsmouth and by that at Shoeburyness, no real difference would appear.

A Committee was now, however, engaged in carrying out systematic experiments with plates of various thicknesses and of improved material. These experiments, at the earlier stage of the manufacture of armour plates, would have been of comparatively small value; but now that previous trials had led to the introduction of a tougher quality of iron, valuable results might confidently be looked for. As to the acts of the Admiralty, which had been so freely criticised, and not unfrequently blamed, it was an easy thing to find fault; but he believed that if the matter were fairly examined, and all considerations duly weighed, a different conclusion would be arrived at.

Mr. Scott Russell had described the 'Warrior' as a 'perfect' vessel. She was certainly a very fine ship; but as a sailor, Commander Scott could not speak of her in the same terms of admiration. There were, however, some points in which, he believed, most persons would allow the 'Warrior' to be deficient, and he would mention them; because if the Admiralty had gone on building ships of the same pattern, and as fast as Mr. Scott Russell advised, it might be asked, what would now be their real worth to the nation? and what could be done with all the present ships?

He thought, that after so much expenditure had been incurred for wooden ships, their utilisation should be first effected; and having in the meanwhile ascertained the best vessels for future warfare, then to press forward with their construction.

In naval warfare, the object so long aimed at,—that of concentrated broadside power,—was now within reach, for steam enabled a vessel to be steadied on any bearing. And hence in a future conflict, instead of trusting, as heretofore, to the uncertain aim of men blinded by smoke between decks, and unable to see the enemy, (much less to judge of the distance, or the direction in which hostile ships were moving,) the Captain himself would be enabled to accurately point all, or any portion of the guns, by the helm of the ship. Precision of broadside fire could be thus obtained, and might be continued with certainty, provided the rudder, which governed the movements of the ship, were protected. But the rudder, on which so much depended, was entirely unprotected in the 'Warrior.'

The rudder should now be regarded as the lever, to turn the whole broadside of guns and to keep them bearing upon the enemy, just as in Captain Coles's very ingenious plan, the shield containing the gun was moved round by a lever, until the gun was correctly pointed.

Again, the 'Warrior' had a vast amount of overhang at her bow and stern, which not only augmented the broadside surface exposed to an enemy's fire, but also greatly added to her vulnerability, by the increased size of the upper deck. Had the 'Warrior' been built inclining inwards from near the water line, she could have been easily covered with armour, especially had the plates been varied in thickness, to suit the different parts of the vessel. This arrangement would have also admitted of the protection of the rudder, which he considered should be within the ship, until below the water line.

With respect to the iron-cased three-decker, proposed by Mr. Scott Russell, he thought such a vessel would soon be shaken to pieces; for the vibration occasioned by the motion of the screw, would be maintained by the enormous weight of the overhanging mass of the stern, covered with armour plates.

This overhang of bow and stern, in the case of the present large screw liners, was, with their long and heavy masts, and their guns, the reason of their uneasiness in a seaway, and the probable cause of their so constantly requiring repair; and he believed, that if the masts were shortened, their number increased, and the superincumbent mass over the screw reduced, straining and damage to the sterns of the large screw war-vessels would no longer be heard of.

He was not in favour of plated line-of-battle ships, but would rather, as already suggested, cut down some of the present liners and build nothing, in future, beyond frigates. The loss in number of guns would be more than compensated by the vessel's being able to carry the heavier armament, that future warfare against plated ships would necessitate.

As to the new ordnance, the only really powerful gun produced was that made by the Mersey Company for Mr. Lynall Thomas; for the finely-grooved 100-pounder Armstrong projected its shot with too low a velocity, and hence it was, that the 'shunt gun,' (with a different system of breech loading,) was about to be substituted for it.

It was stated, that there were thirty thousand pieces of cast-iron ordnance in position; and it might be asked, whether this vast stock was to be thrown aside, in favour of delicate weapons, of which there was not, at present, any positive experience, at an expenditure of more than £10,000,000 which must be incurred. Other nations were meanwhile converting their durable cast-iron guns into efficient rifles, and common sense indicated, that the cast-iron ordnance should be utilised, by adopting a system of rifling, that could be equally well applied to the old, as to the strongest new guns that might hereafter be introduced into the service. Such a plan, and the avoiding any change of calibre, would prevent the danger of a transition state, and enable the simple, yet valuable spherical shot and the other stores to be advantageously made use of.

Notwithstanding the opinions that had been expressed, as to the slowness of the Admiralty, Commander Scott considered that there was great evil in the pressure attempted to be put upon that department. It seemed to him, that on the whole question of the national defences, they should not too readily accept the statements of those who were personally interested in alterations, but should rather aim at making use, as far as possible, of the present materials now in the arsenals and dockyards.

Mr. J. D'A. **Samuda** agreed, generally, in the importance of the Paper which had been read; and he more particularly concurred in the introductory observations of the President; the purport of which, he conceived to be, that whatever might be the value of the fortifications along the coast, the essential and ultimate defence of the country must depend upon the command of the Channel. To retain that command, with the present advance in naval architecture, it was not requisite to go into minute details to be assured, that it must be effected, principally, by the agency of iron-plated ships. The most important points to be discussed were, first, the description of ships which were best adapted to accomplish the object of securing the defence of the country, upon the most perfect system; and secondly, the description of armour plating which would be best adapted for the ships engaged upon this service. These were the two great points to be considered, and he thought the greatest possible benefit would result to the country at large from a decided expression of opinion, from the Institution of Civil Engineers, after having maturely considered the question, of how to obtain the most invulnerable and adaptable armour. It must be admitted, that the description of armour, now used, was very complicated, and in many respects very inefficient. In the abstract, the plan of covering the outside of a ship, with a thick plating of iron, was unquestionably an improvement upon the wooden skin, for resisting modern artillery; but it must be remembered, that this system was virtually hanging an enormous weight upon the sides of the ship, and thus taxing the structure to carry that weight; it therefore became a vital question, and one to which a great deal of thought ought to be given, whether this weight, which was now merely hung upon the ship's side, to resist the enemy's fire, might not be made to contribute to the strength of the ship, for supporting that weight. The system of iron casing was first tried in 1855, and the first iron vessel cased in armour was, he believed, the 'Thunderbolt.' That ship was constructed upon such principles as would naturally occur to persons who had only built wooden ships. The suggestion was, to build the hull with a simple skin of iron, and then to put thick iron plates on the outside, interposing a thickness or backing of timber, between them and the skin of the vessel, to form, as was supposed, a bed, or something which should prevent the plate from being fractured. Mr. Samuda, among others, shared in that delusion, and even though he built the vessel, it never occurred to him, as he afterwards discovered, that the wood backing was utterly useless, in defending the plate, or in preventing it from being broken, if the force of impact of the shot was sufficient to break the plate, without any wood backing. A few experiments showed, that in firing at a target of iron, or steel, which could be penetrated by a bullet of given force, a peculiar description of indentation was made in the plates. If a wooden backing was introduced behind the plates, instead of its reducing the depth of the indentation, it did not appear to alter in any way the effect of the shot; and for this reason, that the particles of the iron were in closer contact than the fibres of the wood, which latter were therefore not brought sufficiently into action, to enable them to render any assistance to the iron before the iron itself was fractured. The 'Warrior,' the 'Resistance,' and the 'Defence,' were built upon the same system, which Mr. Samuda ventured to think was an erroneous one. It was obvious, if the timber, at the back of the plates, was not to render any assistance, it must be objectionable to have it there at all, as it was, in fact, only so much useless weight, as well as introducing complication in construction.

Looking at the question from another point;—a plate 4½ inches thick was placed on the outside of 18 inches of teak; thus representing the same weight, upon the sides of these ships, as if the teak was abandoned and the thickness of the iron plates was increased from 4½ inches to 6 inches. Now from all the experiments Mr. Samuda had made, upon these plates, and from all the well-known facts as to the strength of beams and girders submitted to strain, he had found, as must clearly be the case, that the resisting power was not as the depth, but as the square of the depth of the beam, and therefore, although the weight of the 6-inch plate was equal to that of the 4½ inches of iron and the 18 inches of teak together, the resistance offered by the 6-inch plate was as the square of 6 was to the square of 4½, or as 36 was to 20. Therefore nearly double the resistance was obtained, with only the same weight, upon the side of the ship. That was important, if, as had been said, the guns hitherto produced were only small, in comparison with those that might be expected, and which, it was anticipated, would penetrate all sorts of plates, of any thickness. Carrying the investigation a stage further, it would be found, that the actual resisting qualities of the armour plates existed in the weight and inertia of the plates themselves, and that each plate, upon the side of a ship, must be regarded as an anvil and each ball as a hammer; the weight multiplied into the velocity representing the force with which the hammer struck; and so long as that force was insufficient to remove the inertia of the plate from a state of rest, so long would the plate resist the blow of the ball and it would remain uninjured. If that position were correct, the 6-inch plate must have an advantage of nearly 100 per cent. over the 4½-inch plate, with a backing of timber.

Another almost self-evident position was, to construct the sides of the ship wholly of these thick plates; because it would be manifest, that when once there was sufficient force to destroy the plate upon the side of the ship, so small a thickness as say ¾ of an inch of iron plate, at the back, would be of very little use. If it were admitted, that the whole value of the armour depended upon the inertia, it would be better to incorporate it in the structure of the ship, and thus to render her so much stronger. The effect of this would be, that in such a vessel as the 'Warrior,' which, at present, had only about 200 feet of her midships protected by thick plates and two shot-proof bulkheads, by substituting a shot-proof structure of 6-inch plates from end to end, for the under skin and the timber backing, with the 4½-inch armour plates, there would be attained greater strength, with 6 inches less draught of water, than at present.

Mr. Samuda agreed with Mr. Scott Russell, that it was desirable the Admiralty should make proper experiments, to ascertain the best kind of armour, the value of these deductions, and whether the resistance of the plates was due solely to the inertia, or not. He did not wish to detract from the praise given to Sir Baldwin Walker, in the matter of armour-coated vessels, but he thought, that more might have been done towards ascertaining these facts, which would have rendered the present discussion unnecessary, by having all the facts in question fully and satisfactorily eliminated. It was now exactly twelve months, since Mr. Samuda had urged Sir Baldwin Walker to have such experiments tried, as would ascertain the relative value of plates, with wood backing, and of thicker plates alone; as, also of teak facing, instead of using it as backing, &c., and yet he could not succeed in getting these trials made.

Reverting more particularly to the subject before the Meeting, Mr. Samuda had no doubt, that the command of the Channel was the point to be attended to, for the protection of the country, and he believed, that vessels of smaller size than the 'Warrior,' if properly protected from end to end and having a speed of 11 knots an hour, would be the best and most efficient protection for the coasts of Great Britain, and that was the point which, above all others, should be urged upon the attention of the authorities.

Careful consideration of the question induced the conviction on his mind, that fifty iron vessels, each of about 2,200 tons burthen and 300 H.P., pierced for thirty-two 68-pounder guns, and drawing about 15 feet of water, would form the most efficient and at the same time the cheapest defence for the coasts of England. He had placed before the Admiralty, plans and estimates for such vessels, and he still hoped the Government would see the advantage of relying on this mode of defence, in preference to adopting the much more expensive, and as he thought, less efficient system of permanent fortifications, which at present appeared to engross the attention of the War Office authorities.

Admiral Sir GEORGE R. SARTORIUS said he must admit, that the 'Warrior' was a beautiful ship, and as an admirable work of art did great credit to those who constructed it; but for the purposes of war he considered her an utter failure. The 'Gloire' was 3,000 tons, and the 'Warrior,' 6,050 tons, the steam power of the 'Gloire' being 1,000 H. P., whilst that of the 'Warrior' was 1,280 H. P., the proportion being 3 to 2 in favour of the smaller vessel; and as she was built by one of the first naval architects of France, and with lines calculated for great speed, it was fair to presume, that with comparatively greater H. P., less bulk, and fine lines, the 'Gloire' would have the advantage in velocity, whilst the cost of construction was probably about one-half that of the larger vessel; that of maintenance would be about one-third less. As the beam of the 'Gloire' was greater in proportion to her length, than that of the 'Warrior,' and the actual length of the 'Gloire' was full one-third less, and supposing the speed to be even something inferior, every sailor knew that the 'Gloire' must be more agile and nimble, or much quicker for manœuvring, and would require less space to turn in and for tacking and wearing. These points of superiority rendered it impossible for the 'Warrior' to run on board of the 'Gloire' if the latter wished to prevent it, and the same advantage of speed would enable the 'Gloire' to choose her position for disabling the rudder, or screw, of the 'Warrior,' by her artillery, or her beak, and probably, in action, to knock away the masts of the latter vessel. This could not be done to the 'Gloire' by the 'Warrior,' as the schooner rig of the former enabled her quickly to get all her sails and gear down on deck, or on a level with her bulwarks, leaving nothing but the bare lower masts with two, or three shrouds on each side. It was even stated, that the lower masts were made so as to be laid down nearly horizontally, whilst the bowsprit ran in, and her ram stem, which projected under water, was then ready and clear for crushing in the bow, side, or quarter of the enemy, at the fitting moment; or by sweeping across the stern of the 'Warrior' with that projecting submerged stem, she could disable both the rudder and the screw. The 'Gloire' could bring her perfectly protected and powerful stern, or bow batteries, to bear either for single action, chase, or retreat; whilst the 'Warrior' had not anything of the kind. No wreck of the 'Gloire' could foul her screw. She was invulnerable all round, to ordinary shot or shell, and when she engaged only with her bow guns, the oblique surfaces then presented by her sharp bows, built on the angular principle, gave her perfect immunity against any known projectile. The 'Warrior' had the masts, yards, and sails of a heavy first-rate, or 90-gun ship, some, or all of which, would most likely be shot away in a contest with the 'Gloire,' and then the fouling of the screw was inevitable. It must be borne in mind, that the falling of wreck, in an action, did not occur all at once, so that by making a sudden stern board the vessel would clear herself; but the mischief was going on piecemeal, and a single rope was sufficient to foul the screw, or to drag in a large mass of wreck to cause the injury. With the wind ahead, or on the bows, and according to its strength, the resistance presented by the heavy masts, yards, and rigging of the 'Warrior' would not only give the advantage of some knots, to a vessel rigged so simply as the 'Gloire,' but it would also impede the quickness and rapidity of manœuvring. The merit assumed, for placing the shot-proof armour only in the centre of the vessel, and the mode of doing it, betrayed a singular ignorance of the requirements of a ship for war purposes; and he could not help thinking it was equally a great error architecturally. The two portions towards bow and stern, were comparatively light and buoyant, without armour plating. The centre sustained the whole weight of the armour plate, which terminated abruptly in perpendicular lines, from top to bottom, so that in a heavy sea the centre would remain a ponderous and inert mass, whilst the two ends would yield and twist about with the force of the waves; this unequal action, if it lasted, would lead to the most serious results. The great draught of water and the unwieldy length, which, in case of any accident to the screw, would necessitate a mile of deep water to enable the ship to wear in, rendered the 'Warrior' of little, or no use against batteries, where, to do any good, she ought to be able to approach to within 300 or 400 yards. It was more than probable, that Whitworth's flat-headed oblong shot, meeting with a comparatively flat surface, would penetrate the side of the 'Warrior.'

Another great defect, arising from this mode of placing the armour plates, was that in chase, or in retreating, having no bow, or stern battery, the 'Warrior' would be obliged to keep away, or to luff up almost at right angles to her course, to get her effective battery to bear upon the enemy. This manœuvre would not only cause her to lose at least half a mile, (keeping away and hauling up), but it would be impossible to execute running near the shore, in shoal water, &c. The 'Gloire' had not any of these serious defects; her broadsides were protected in the same way as the 'Warrior's,' and her bow and stern, the most vulnerable and weakest points of the 'Warrior,' were perfectly invulnerable, and were the strongest points of the 'Gloire.' All these qualities, combined with her greater quickness and lighter draught of water, would render the 'Gloire' useful under innumerable circumstances, where the 'Warrior' would be perfectly useless. That the 'Warrior' would be able to work her main-deck guns, when the 'Gloire' could not do so, was, he believed, quite true, and equally so that she could carry more fuel. But these points were of little value, as applied to a contest, between the two vessels. If the 'Gloire' desired to avoid a contest on account of bad weather, or for any other cause, she had only to put herself head to wind, and she would soon leave the 'Warrior' miles behind, besides which she could always work her stern guns, in any weather. Although the 'Warrior' had double the tonnage, the 'Gloire' had much the stronger protected battery. It was a mistake to suppose, that the fire from the upper deck of the 'Warrior' could plunge down on the deck of the 'Gloire' and destroy the men working at the guns. In the first place, those elevated guns of the 'Warrior' were unprotected, and the difference of height was practically insufficient for such a purpose; besides which the 'Gloire's' protected bulwarks were much higher than the men's heads on board, when working at their guns.

In making this comparison between the two vessels, Admiral Sartorius did not mean to assert that the 'Gloire' was by any means a perfect vessel; but he wished to show that the French were acting upon a system based on truer principles, than appeared to be followed in the Royal Dockyards of this country. But that which, in his opinion, constituted the greatest superiority of the 'Gloire' over the 'Warrior' was her character as a 'vaisseau bélier,' or steam-ram. If every gun were taken out of the 'Gloire,' and there was conceded to her only a slight advantage in speed and quickness of movement, she would always be able as a shot-proof steam ram to destroy the 'Warrior,' as he had already stated, by knocking away the masts and gear, and so fouling the screw by the wreck hanging alongside, or by sweeping across the stern, and with the immersed projecting stem encountering the rudder, or the rudder post of the 'Warrior;' which vessel would then become an inert log on the water, without steerage power, or serviceable screw; or by a daring but cautious movement, crossing the bow, to carry away the cutwater, bowsprit, and probably the foremast, when the wreck of the bowsprit alone would be sufficient to foul the screw. In any of these cases the ship would be disabled and become unmanageable, and could not avoid the blow from the ram, which, as had been correctly observed, would "break in her side, as a hammer would crack the shell of a lobster."

It was needless to point out by how many ways and means, well known to sailors, boarding could be rendered impossible, between two such vessels, particularly when one possessed the advantages already named, of handiness and quickness in answering the helm, and having no projection of any kind to hook, or entangle with her enemy.

For the protection of the coast from invasion, there could not be any doubt as to which was the superior ship; as also for running into an enemy's harbour, amongst the vessels at anchor. A single touch of the beak would produce an effect which hours of cannonading could not insure. In such a case the 'Gloire,' used as a steam ram, would be able to do well and effectively what the fire from half a dozen 'Warriors' could never accomplish. Had the 'Warrior' been taken to pieces before launching, two noble improved 'Gloires' could have been constructed from the materials; or by taking away the bowsprit and cutwater, giving to the 'Warrior' a simpler rig, that vessel would have been much improved. This would have been real economy, as the country would then have gained two effective vessels, instead of one unwieldy and unserviceable ship.

It had been asserted, but he conceived it must be an error, that the 'Warrior' was never built for, nor intended for a steam ram. He had a copy of the instructions issued to the builders, and in them the vessel was described to be built "strong enough to sink by a concussion, and to be guarded against the effects of collision." A steam ram could not be more clearly and distinctly described, and her real stem was identical with those of the two admitted rams. The cutwater was added, and was evidently a subsequent thought, and merely for the purpose of giving symmetry, thus sacrificing her most formidable power.

A revolution in the tactics of naval warfare and of naval construction, as great as that introduced by the use of gunpowder, had commenced. The old noble timber line-of-battle ship, even in its improved transition form, with a screw propeller, might now be considered as a thing of the past. But what forms of construction, what types, and what materials were to succeed the wooden walls; whether the future vessels of war were to be altogether, or to what extent, shot-proof;—whether the power of sinking by a blow, or concussion, was, or was not to be combined with the use of artillery, or to be rejected altogether;—what were to be the best means of affording the effective protection against the greatly improved and still improving projectiles of the day;—whether timber and iron, or iron alone, ought to be used in the construction of the future war navy;—the kind of men to be employed;—these and many other connecting considerations of deep interest to all civilised countries, but profoundly so to the British nation, were matters that required immediate and anxious investigation. It could not be any disparagement to the Admiralty to say, that the weight and variety of talent, practical skill, and scientific knowledge, which the present important crisis demanded, could not all be found in the Admiralty department alone. It was a moment in which the distinguished fitting and competent talent of the nation ought to be laid under contribution, to advise and to suggest, as to what was wise and right to be done. From the conclusion of the American war, as also after the Russian war, Admiral Sartorius had pressed for the nomination of a "Commission of well-known names, Artillery Officers; Civil Engineers; official and private Ship-builders, in wood and iron; practical Sailors, acquainted with war; intelligent Civilians, such as owners of yachts, or who had taken interest in naval matters." Every information should be laid before them, that the Government could give; the right to call and examine competent persons, and even to direct experiments to be made, should be accorded them, and then the report of their views would be useful to the Government. This was one of the few cases in which there would be wisdom in a multitude of counsellors.

A Royal Commission was appointed to look into the state of the country, for defence against invasion; to examine the various means and resources, possessed for the purpose, how they might be extended, strengthened, and improved; and to make any further suggestions they might think proper, to save the country, if possible, from so fatal a calamity as a successful invasion. The strange questions put by the Commissioners to Lord Overstone, would seem to show, that notwithstanding the able opinions of the noble lord, quoted in the Report, showing the terrible consequences of such an event occurring, they did not appear to have attached much importance to the safe landing of a hostile army on the coast, and that they had even contemplated, as possible, the possession of the capital by the enemy. The Commissioners recommended the fortifying of certain points, but they admitted that there would still remain about three hundred miles of undefended coast where an enemy could land, on the southern shores of England alone. Yet they did not propose any means, except reliance on the Channel fleet, for preventing, or even for embarrassing the debarkation of a hostile army, on those portions of the undefended coast.

The question now to be asked, was of the deepest importance. Had not the Commission overlooked various modes and means, by which such a landing could be seriously embarrassed, if not be altogether prevented, and independent of the Channel fleet? Now Admiral Sartorius maintained, that they had not done so, and he was prepared to show, that there were means simple, economical, and powerful, whether taken singly, or in combination, which were amply sufficient for the purpose.

The Commissioners, also, did not notice the most important element towards success, for repelling invasion by sea;—the extraordinary improvements lately made, and still progressing, in the calibre, correctness of aim, and extent of range, of fire arms, of every size and description, and the vast increase in the powers of destruction of the projectiles used from them. They were only alluded to, cursorily, as likely, in a naval battle, to cause both the victor and the vanquished to be disabled, sooner than by the old artillery. A little reflection would have satisfied the Commissioners, if such an event would be the probable result of an action between fleets, on unsteady decks, with thick smoke between decks, how infinitely greater the destruction would be when such artillery and rifles would be used against vessels of war, transports, and boats, from the steady platforms of the shore. The enemy, until a disembarkation was effected, could hardly avail themselves of any of the advantages arising from these improvements. The guns on shore, firing from isolated and masked points, would necessarily be almost invisible objects, whilst the ships and boats were large objects, that could scarcely be missed by cannon, or rifles. Thus, all these improvements being almost entirely on the side of the defenders, gave a hundredfold superiority to the defence, as against the attack by sea, and rendered it evident that if some ten thousand riflemen, or eighty or a hundred field-mounted improved artillery, could be assembled at the moment the enemy was about to disembark, the latter must fail in his attempt, if these means were employed. These means Admiral Sartorius would endeavour to point out.

Before entering upon a description of the three systems of defence not alluded to by the Commissioners, it was necessary to notice what he assumed to be the clear inferences of the Royal Commission.

1. The first object of the enemy, on a successful landing, would be to march upon London:—thus proving, (unintentionally,) that the extensive works proposed by the Commission were no protection against the two most fatal events that could possibly occur; namely, the landing on the coast of a powerful hostile army, and, as a consequence, the more than probable capture of the capital; yet, strange to say, the Commissioners quoted the opinion of Lord Overstone, illustrating in a most able and truthful manner all the terrible and irremediable evils which must ensue on the occurrence of either event. 2. An enemy's army would land in two, or three hours, unseen, on the coasts, and the insular position of the country was a disadvantage, if the Channel fleet should be absent; and the channel fleet was the only valid security against the debarkation of a hostile enemy on the coast.

He admitted, that whilst a powerful fleet was cruising in the Channel, successful invasion was all but impossible; but there were many reasons, why implicit reliance for protection should not be placed in that kind of protection. Some of them were stated in the Report of the Commission; such as the fleet being disabled by a gale, or even by a successful battle, or when it was called away to pursue the enemy's fleet, &c.

There were various systems of defence, which were not noticed by the Commissioners:—

1st. Coast rail and tram roads;—batteries of heavy mounted field-guns at each coast-guard station, the men there being well trained to work them;—small entrenched camps between coast towns, if the latter were more than fourteen, or fifteen miles apart, these serving also as rallying points for the volunteer artillery, or riflemen;—a few gun boats, (row gun boats would answer quite well enough,) each carrying one heavy gun in the bow and a howitzer aft, not to be of more than 50 or 60 tons, and the draught of water not exceeding 3 feet 6 inches, the guns being so fitted as to be landed easily when required. The gun boats should be stationed in any of the adjacent small harbours. As an attempt at landing could not be made, except in moderate weather, when a boat full of troops could swim, the gun boats would unquestionably be able to do the same. Look-out towers on convenient heights, telegraph wires communicating with all the military stations in the kingdom, and one or two great central encampments; with fast steamer videttes watching the ports where the enemy had, or might have assembled fitting vessels for the embarkation of troops. Even totally irrespective of premeditated invasion, there was nothing he had stated, beyond what it was absolutely incumbent to adopt, for the protection of the coasts against sudden, or predatory attacks of an enterprising and energetic enemy, whose object would be to keep his foe in a constant state of anxiety and alarm by the means afforded by steam.

Supposing these arrangements to be placed on a good footing and to be kept in working order, and the military means rightly organised, many hours must elapse, from the first alarm, before an enemy's fleet and convoy could leave his harbour, come to anchor, get the boats out, the troops embarked and marshalled in divisions, &c.; surely if moderate energy and vigilance were used on the coast, and with the machinery already described, in fewer hours still, double the force could be assembled on any menaced point. The artillery being spread about, and so placed as to be almost invisible to the enemy, at such distances would afford perfect impunity, as it could not fail to hit such large marks as the ships. The riflemen, behind rocks, or hid in pits, would have for targets, large boats filled with men, which they also could scarcely fail to hit. Supposing, then, that out of sixty shots from each man only five hit, this, added to the destruction made with cannon shot, shell, and grape, how could a successful landing be effected under such circumstances? Ships on fire, boats sinking, men drowning, or killed, or wounded, in thousands, the few who reached the shore would only do so to surrender as prisoners of war. It must also be remembered, that the whole of a large army could not be disembarked at the same time, for want of a sufficient number of boats.

The vast steam mercantile navy could also be properly armed and organised, so as not to interfere in any way with their commercial duties, except at the time of an invasion; and unless the enemy was supported by a powerful war fleet, an attack could not succeed against such a force as, if well arranged, could be formed from the mercantile navy. This would be indeed a very useful Channel fleet, and would contain some of the finest vessels for the purpose, and which were always on the coast, ready for use. To man them the ocean and coast sailor population, fishermen, river, barge, and boat men, and pensioners, amounting to about 250,000 men, would amply suffice, if under a proper arrangement and system.

The next and most infallible means of defence were the steam-rams, properly constructed; these, even without shot-proof protection, would be perfectly effective against transports and would be formidable to the largest men-of-war. An invasion would be absolutely impossible in their presence.

These three systems of defence, (not noticed by the Commission,) were efficient separately, but would be perfectly invincible, if in combination. They were applicable to every part of the coast, and the power of using them was due to the insular position of the country; and all these and the Channel fleet must be destroyed, before Great Britain could be reduced to the level of a continental nation, and be obliged to fight a battle for its salvation against a hostile army on her own shores.

That a nation like this, either at war with, or regarding with suspicion an active and enterprising neighbour, amply provided with every requisite for an invasion, should neglect the ordinary preparations and military precautions of war, be so unprovided with the common means of defence, and so blindly unvigilant, as to permit a large hostile force to assemble on coasts almost within sight, leave his port, and effect his landing upon the coast in two or three hours, and moreover to maintain his position, in spite of the efforts of the country, and then to cover the landing of the main body of the invading army, was a chain of improbabilities, which could hardly have been expected to have been found, even hinted at, in a Report proceeding from professional men.

Mr. J. Lawrence remarked, that the question of the National Defences resolved itself into two methods;—to strengthen the defences either by iron-plated ships of war, or by using stronger and more effective guns. Now an armour-plated ship required at least two years to construct. Mr. Scott Russell was of opinion that the 'Warrior' would prove to be a faster vessel, than the 'Gloire,' although the former had not yet been tried; but he had stated, that the vessels which were to succeed the 'Warrior,' would be comparatively slow. Therefore it was clearly a matter of chance whether the service was advancing or retrograding in this respect. Supposing however that the country was progressing in a direction which had been unquestionably ascertained to be the right one, it would be a long time before anything like a large fleet entirely covered with armour plates could be created. It was, therefore, necessary to look for some other means, and attention must be directed to the rifled cannon, of which so much had been heard. It was a delicate matter to speak of this subject in this assembly. The position filled by Sir W. Armstrong was a high and responsible one, and without wishing to detract from the talents of that gentleman, Mr. Lawrence could not help taking exception to the appointment, as it was calculated to check improvements in artillery by others, who could not have the facilities enjoyed by Sir W. Armstrong.

It was impossible to discuss the subject of the National Defences without alluding to the question of rifled artillery, which was the main feature of modern warfare; as the broadside guns of the British navy had been the most important of the National Defences. At the present moment there were at least six, or eight gentlemen engaged in making improvements in artillery. The object was a national one, and ought not to be restricted to the advantage of any one individual, as was now notoriously the case. Experiments had not been made with suitable projectiles against iron plates, nor could such experiments be made until proper guns were employed. Such experiments were impossible, if the authorities refused to employ, or even to try any other than one kind of gun. For instance, the gun invented by Mr. Lynall Thomas had been stated not to have been tried at all by the Government, and thus, if it possessed any merit, it was prevented from being exhibited solely by official routine. The experiments should, in his opinion, be made publicly, and by persons who were independent of the Government, as it was morally impossible when the Government had adopted one particular system, that any other could receive a fair and impartial investigation.

Lieutenant-Colonel **Jervois**, R.E., was of opinion, that there was an advantage in having the opportunity of discussing the subject of the National Defences in the theatre of the Institution of Civil Engineers.

It was desirable, that a question of such vital interest to all classes, and to every member of the community, should be discussed openly and fully, and the more it was discussed the more probable it was, that the public would have correct views upon the subject. Perhaps, also, those whose duty it was officially to consider the question might benefit by it, although they might not agree in some of the 'political' statements with which the Meeting had been favoured. He would rather altogether pass over and avoid the crimination and recrimination, which was likely to arise, if the valuable time of the Meeting was occupied in attacks upon the Government departments and upon Military Engineers.

As the question under discussion was the "National Defences," it appeared advisable to keep to that point, as much as possible, and, if hereafter any member of the Institution wished to write a 'scientific engineering' Paper on the construction of the Board of Admiralty, or on the merits of any of its members; or if another desired to examine the materials of which the War Department was composed, and the mode of putting those materials together, no doubt some interesting information might be obtained; although discussions on those matters might perhaps be subject to the remark, that the Institution of Civil Engineers was rather widening its field of scientific action, and it was not impossible that it might draw down upon itself the animadversions of Mr. Bright, for encroaching upon the privileges of the House of Commons.

He did not believe, that the Royal Engineers professed to be infallible, nor did he suppose that the attribute of infallibility was claimed by the Civil Engineers; a body for whom he, however, entertained the highest respect.

He quite agreed with the Author of the Paper, in his remark, that the question was one of great intricacy, and that correct conclusions could not be arrived at, without taking a comprehensive view of the subject. The time of the Meeting required that the speeches should be as brief as possible, therefore he would confine himself to the leading points of the question.

In considering the national defences, it was evident that the question was one which affected the whole British empire. The protection of the colonies, of commerce and of the mercantile marine was the duty of the navy. If the British navy was not superior at sea, the foreign possessions could not be held; and therefore, in considering the naval means, the construction of the ships of which that navy should be comprised, and the whole system of defence, the discussion must not be confined to the question of the protection of the shores of Great Britain, although that, no doubt, was the most important consideration of the whole.

Independently of those foreign possessions, held for purposes of colonisation and commerce, there were others, such as Malta and Gibraltar, the Island of Mauritius and the Bermudas, which were kept either as centres for the navy abroad, or to prevent other nations from taking possession of them, because of the vast injury their possession, by an enemy, would inflict upon the English commerce, during a period of war. Those places were fortified and garrisoned, so as to enable them to hold out, during the absence of the fleet; but it could not be hoped to retain them permanently, without a naval superiority over any nation, or combination of nations, with which this country might chance to be at war.

The ominous remark, made by Prince Napoleon, in his late celebrated speech before the French Assembly, would be generally remembered, when he said, "that the navy of France aspired to be the centre of all the secondary navies of Europe." This was a pleasant prospect, when some of those nations were making great efforts to increase their navies.

The more the question was considered, the more clearly it would be seen, that the navy had no slight work to undertake in Europe, independently of the great object of the defence of the British shores; and it must be remembered, that it was not only Europe that was to be considered, but the colonies had to be cared for, as well as the commerce of India, China, Australia, the Cape Colony, the West Indian, Canadian, and Mediterranean possessions; in fact, of nearly the whole world.

These points were mentioned, in order to show how necessary it was for the navy to have a power of free action, that it should be capable of uniting its strength, wherever it might be required, either for aggression, or for defence. This implied, that it could not always be present at any particular place, and that as small a portion as possible of the naval means should be tied down to any stationary duty.

It was very common, in projects for defence, to find that the whole of the system, for protecting a particular spot, or at all events a main portion of the system, consisted in a proposal for a number of block ships, or floating batteries, and, taking each project by itself, the demand appeared to be reasonable; but in putting the whole, or any large portion together, it would be found, that the result would be an addition to the navy of this country, which neither its resources in money, nor in sailors, could supply.

There was no doubt, that the maintenance of the power of this country, and the protection of its shores, must depend mainly upon the active moveable navy; and if that navy was to be efficient, it must be large enough to cope with all that could be brought against it; its motto must be 'ubique;' it must be free to unite in force and to act with vigour and effect, wherever it might be required; and though last, not least, it must have in its composition a great number of armour-plated ships,—many more than it now possessed.

He had entered, somewhat at length, into the consideration of the duties that the navy would have to perform, in case of war, because he wished to show that occasions might arise, when the fleet might not be present, to defend the coasts, and that if it were obliged to be kept at home, at all times, some great disaster abroad might occur.

The glorious Volunteer movement was an evidence of the belief of this country, that it would be wrong to trust to naval means alone, for the defence of the coast. It might be believed by some, that France was powerless as an assailant; but, when it was recollected how nearly the projects of the great Napoleon had succeeded, even without any of the advantages for combination, which now existed,—when it was considered, that all the armies of France might be scattered over their camps and quarters, and their naval means distributed in various places, in such a manner as to give no grounds for suspecting an attack,—yet that, by means of the electric telegraph, the troops might be set in motion, and the periods of their arrival at the coast and the departure of the squadrons carrying them, be so calculated, that they might all arrive at a given time, upon any point of the coast, and that that point must be unknown to the defenders, it must be confessed that the descent of a hostile force upon this country, did not seem so very improbable.

No doubt steam, railways, and electric telegraphs were available for defence, as well as for attack; but there was this great difference, that the side which took the initiative must have the advantage; the attacking enemy knew, previously, where he was going to, and exactly what he proposed to do, what feints he was about to make, and how to puzzle the defenders: whilst the side which occupied an insular position, and received the blow, must be on the look-out everywhere; and if its forces were hastily moved at the first signal from the electric wire, they might arrive at the point to which they had been summoned, just in time to receive another telegram, informing them that the enemy had landed in force, in a totally different quarter. This was not, however, any argument against improving the railway and telegraph systems, which, if used with judgment and deliberation, would be most valuable accessories for defence. It was, however, an argument against relying upon steam, railways, and electric telegraphs, as the main elements of a comprehensive system of defence. The means of communication for armies and navies, and the power of conveying intelligence, were raised by these means to the highest pitch of perfection, but the fundamental principles of warfare were not thereby altered.

There were two conclusions which must be arrived at:—

1st. That the fleet must be free to move, wherever it was required.

2nd. That an enemy might, during the temporary absence of the fleet, effect a landing upon the coast.

If there were occasions, when the fleet must quit these shores for a time, care must be taken that, when it returned to the Channel, it found its homes had not been despoiled, during its temporary absence. It was evident, that if the naval ports and dockyards, where the fleet had been formed, and from which it had been sent out, to do its duty, were left unguarded, an enemy might destroy the naval power of the country, at its very source, and that, at a minimum amount of cost and trouble, by a sea attack upon those places. Therefore it was all-important to defend those ports and arsenals to seaward. Then came the question, how could this be best done. It was often advised, that it should be effected by floating batteries stationed at the ports, for the express purpose, but he thought that the mode of doing it, with the greatest efficiency and the utmost economy, was mainly by fortifications. No doubt floating defences were in some instances required, as auxiliaries, and perhaps steam rams might, in certain exceptional cases, be used with good effect. But a floating battery was a much more expensive article than a fort; its first cost was greater, and whilst the latter was permanent and lasted for centuries, and could be maintained at a very small cost, the former was perishable, and required frequent costly repairs and periodical renewal; its gun platform, moreover, was unstable, and its accuracy of fire, therefore, could not be compared with that from a fort.

Besides, if the country were to rely on ships, alone, for its defence, a force must be stationed, permanently, at each port, equal to any that was likely to be brought against it, in the absence of the fleet; an inferior force would be no defence; and as these vessels must, to a considerable extent, be manned by sea-faring men and be commanded by naval officers, they would abstract so much from the sea-going fleet; whilst if attacked by a superior number of ships of equal power, their only alternative,—unless they stayed to be captured,—would be to run away, and to take refuge at the nearest point, where refuge could be found.

On the other hand, forts could be rendered as invulnerable as the circumstances of each case required; their gun platforms were perfectly stable, and were capable of carrying ordnance of any weight: for instance, in the proposed iron forts, at Spithead, it was intended to have 300-pounder guns, and even larger, if practicable. Again, a fort could be manned, to a great extent, by men with a comparatively small degree of training; it was always in its place, ready for work, whilst floating batteries might be anywhere; at the same time the fort immensely increased the power of,—indeed it rendered useful where otherwise it would be useless,—any small force of floating defences that might be upon the spot, at a moment of attack.

Enough had been said, although no doubt a great deal more might be urged, to show that the naval ports and arsenals must be fortified, at all events, to seaward.

Such places as Portsmouth, Plymouth, and Pembroke, must be fortified, for the protection both of the harbours and the dockyards.

Some others, such as Portland, must be fortified principally for the sake of the harbours, both that they might be safe refuges for inferior squadrons of the fleet, and for preventing an enemy from obtaining possession of them. And here it should be remarked, that it was a fallacy to suppose, that harbours, of themselves, were a defence. Harbours, to be a defence, must be fortified; otherwise, if they were in positions favourable as bases for attack, like those just mentioned, they were likely to become valuable to an enemy.

Fortifying the dockyards and naval ports, so as to set the fleet free, to concentrate its strength wherever it was required; so that the harbours might afford secure refuges for an inferior squadron of the fleet; and so that an enemy could not take possession of them, during the absence of the fleet, was widely different from fortifying the coasts. The entire coast could not be defended by works of fortification, and there was not any intention of making the attempt to do so.

The Author of the Paper referred to "£12,000,000 having been voted for the construction of military coast defences." That term was incorrect, and the amount of money which he stated was also wrong. The fact was, that the amount which had been sanctioned by Parliament, for new works of fortification, recommended by the Defence Commission, was only £5,000,000, and only £2,000,000 had actually been voted.

Now considering the supposition of an enemy in force, attempting a landing on the coast, during the absence of the fleet. He must be disposed of on the landing-place, if possible; but he had before shown it was probable that this might not be done, as any descent on England would only be attempted by a very large force, and under favourable circumstances. Then as to the system of defence, to meet such a contingency, the probable nature of the attack must be considered, and no doubt the object of an enemy would be to do as much injury as possible, in the shortest time. If he only intended sending a small expedition of,—say 20,000 or 30,000 men,—he could effect this object by attacking the dockyards by land. For the same reason that he would attack them by sea, if they were not fortified to seaward, he would attack them by land, if they were not defended to landward. With the power of transport, already possessed by France, an attack of this sort would require no previous preparation, calculated to raise suspicions in this country, and it might take place with the utmost rapidity and suddenness. Still, if successful, although it would do an immense amount of injury, both to the power and to the commercial interests of the country, and would lower the *prestige* of Great Britain; yet such an expedition would not bring the British nation to terms. To do so, an enemy must possess himself of the

Capital, and to effect that he must undertake the invasion on a very large scale. To meet such an attack, the nation must be prepared with all its available forces to oppose the enemy,—on the beach, if possible,—and if not on the beach, at some previously-selected positions inland.

But in order to distract attention, the enemy would no doubt make a simultaneous attack, on some other points. It was thought, by some, that such a diversion might be tried in Ireland. This might, however, be doubted;—the actual circumstances of Ireland were very different from what they were sixty years ago, and an invader who expected to induce the population there to join him, would find himself greatly mistaken. It might rather be expected, that the diversion would be upon one of the dockyards; indeed, it was known, that such a scheme had entered into the calculations of foreign generals.

If, then, it was required to mass the troops, as much as possible, to defend the heart of the empire, arrangements must be made, that the army would not have to manœuvre, for the defence of the other places referred to. This could only be done by fortification, by means of which they could be defended, to a very great extent, by the partially disciplined forces which could be gathered from the population, whilst the manœuvring army was set free, to meet the enemy in the field. An additional reason for fortifying these places to landward was, that they afforded capacious strongholds which would prove important rallying points, depôts, and places of refuge for considerable districts, where scattered detachments and volunteers might be collected, organized, equipped, and then be disposed of, as might seem best;—thus Portsmouth, Plymouth, Dover, &c., would each become a focus for refuge, or for action.

It was argued, however, that the fortifications required so many men to garrison them. To that it might be answered, that if these places were not fortified, there would be required, not only double, or treble the number of men, but a much greater number of disciplined troops than it would be possible for this country to maintain.

It therefore appeared, that these places must be fortified to landward. Indeed, the fortification of them, both by sea and land, was simply the best method of defending them, with the least possible number of men and ships. In short, the effect of fortifying the dockyards and arsenals was, to provide, at the smallest cost, so much addition to both the regular army and the fleet.

But it might be asked, why the Capital itself should not be fortified, as a successful attack upon it was represented to be so disastrous an event? Now, premising that the term 'fortifying London' led to a great deal of misconception, and that it was an incorrect term, he did not hesitate to say, that there ought to be permanent defensive works, which would form fortified fields of battle, in the vicinity of the capital. Whether they should be in the form of intrenched camps, at a distance from London, or whether there should be a chain of forts all round, nearer to London, was a question for consideration. Although the latter project might be preferred, either would be good; but he should be glad to have whichever, after the fullest discussion, might be decided on. The expense was, no doubt, the great obstacle to any project of the sort being undertaken, and there were many eminent men who did not concur in the proposal.

The first duty, in case an enemy landed, would of course be to oppose his advance by every possible means; and in destroying the roads and bridges, as well as in opening out communications and affording assistance in many other ways, the services of the Members of this Institution, if incorporated as a staff corps, would no doubt, as the Author of the Paper said, be eminently useful. Next, a battle must be fought, for the defence of the Capital. The fields of battle must be carefully selected beforehand; and they should be fortified by earthworks, on plans previously made, so as to enable the battle to be fought on the most advantageous terms. And here also the services of the Civil Engineers would be most valuable. No doubt they could organize large bands of men, and apply them to the execution of these works, in whatever quarters it might be determined to fight the battle. Although with these preparations it must be hoped, that the enemy would be vanquished, yet it would be consolatory to feel that, if that battle were lost, there was strong support to fall back upon, and that there were the means of holding the enemy at bay, until all the power of the country could be applied to crush him. This would be effected by permanent defensive works near London; and one great value, above all, of such works, would be that a knowledge that the nation was so fully prepared, would put the idea of a great invasion altogether out of the head of any power, which might otherwise think of attacking it.

It was commonly said, that "all our men would be locked up in forts:" the fact, however, was not so. The works would be garrisoned by partially trained forces from the population, which might not be sufficiently advanced in their drill to take the field, and which, without the works, would be comparatively of very little use. It was constantly stated, that there was no use, in permanent works of fortification on land, because 'earthworks' could be thrown up at any time. By 'earthworks,' those who held this opinion meant, of course, temporary earthworks, because a work of fortification on land was equally an earthwork, whether it was temporary, or permanent. The great difference was, that the permanent one was a strong earthwork, whereas the temporary one was a weak earthwork. The strengthening of a field of battle, by works thrown up at a moment of expected attack, behind which disciplined troops were to fight against an army about equal, or only a little superior in number, to themselves, was quite a different thing from fortifying a place, so that it might hold out, when garrisoned by forces either very inferior in numbers, or in quality, or in both, to the army by which it might be attacked, even when every allowance was made for the superior bravery of the defenders. In the latter case, the works were required to be such, that the garrison would feel in perfect security, by reason of the strength of the works.

It could not be expected, that an inferior force of undisciplined men, however brave, could resist the rush of such troops as a body of Zouaves, for instance, if there were only a mound of earth and a small ditch in front, up which the Zouaves, or other active troops, would rush like hounds. But if they were placed in works, with good bomb-proof cover to them, with deep ditches, and sunk perpendicular escarps, 30 feet in height, and well flanked, they would feel perfect security, and would be able to work their heavy guns deliberately and with good effect.

But besides these considerations, there was the great advantage, that the permanent work had its armament, its ammunition, and all its appliances for defence ready, whilst all the appliances for arming the fieldwork had to be obtained from perhaps no one knew where, and that at a time when all the resources would be taxed to the highest degree, and when it was not unlikely that considerable confusion might prevail.

It was not necessary to allude further to the details of the construction of fortifications; he would prefer to benefit by hearing the statements of others on this point. At the same time, he begged that it might be understood that he was not in the least desirous of avoiding the consideration of the question with any one.

But in questions of so complicated a character as those now under consideration, it could not possibly be expected that all should agree. The strength at which the navy and the army should be maintained,—the mode of construction of the iron-cased ships,—the precise extent of the fortifications, and the character of construction to be adopted in each case,—would probably always be more, or less, subjects for discussion; but all must agree, that if there was to be a comprehensive system of defence, for the British empire, each element of defence must have its place. A large and efficient fleet, including a considerable proportion of armour-plated ships, was a first and paramount necessity; the army, including the militia and volunteers, should be maintained at as great a strength as possible; but neither the sailor, nor the soldier, could afford to dispense with the aid of the Engineer.

Mr. Hawkshaw, V.P., thought the scope of the Paper had been extended beyond what was originally intended. No doubt "The National Defences," in the extended sense of the term, applied to the colonies, and to every interest in which the nation participated; but he apprehended, that the Paper had regard chiefly to the defence of Great Britain alone, and unless the discussion was limited to that branch of the subject it would open too wide a field of inquiry.

The subject was new to many present, but it had brought together many gentlemen of the Naval and Military professions, as well as Civil Engineers, and the Paper would therefore be useful, in leading many, who hitherto had not thought much upon the subject, to devote their attention to it, particularly with regard to the question of construction, with which, as Civil Engineers, they were chiefly concerned; for he considered questions of military and naval strategy hardly fell within the province of civilians.

There were however one, or two obvious points of remark. For instance, they had all heard, or seen, at different times, elaborate arguments put forward, to prove that fortifications alone would not avail for the defence of the coast. No one practically acquainted with the subject would say, that fortifications alone, on the shores of this country, would afford sufficient protection from foreign invasion.

On the other hand there were many who asserted, that fortifications might everywhere be dispensed with, if there were only enough of properly-armed ships. Any one who reflected upon the subject would see, that it was quite impossible to provide for every emergency in that way; it was not practicable to have ships in readiness to fight a battle at every point where invasion was practicable, or where mischief from an enemy was possible. This view of the subject was advanced, in antagonism to the universal fortification system. Both were extreme views. There might be certain places, where it would be judicious to have fortifications. He did not pretend to specify them, though some of the cases in point he thought were sufficiently apparent. For instance, there were certain points on the Thames, which were comparatively defenceless; and it was evident that it would be desirable to fortify the principal arsenals. There was one point to be considered, in comparing forts and ships. It was clear, that a fort might be rendered so strong as to be almost impregnable. If a thickness of 10 inches of iron would not suffice, it could be increased to 12 or 15 inches; and if that were not sufficient, it could be made even stronger still; therefore it was quite practicable to render a fort impregnable, as against attacks from ships. But a ship could not be rendered proof against projectiles from a fort. A ship must be buoyant, and be capable of moving with a certain velocity through the water; and there was a limit, therefore, both to the weight of the armour plates and of the guns of ships. Then, inasmuch as a fort could be rendered impregnable, and could mount guns of a weight which would be impracticable on board ship, it followed, that in certain cases, the fort would be superior.

There were some other points of construction, to which it was desirable that Civil and Mechanical Engineers should turn their attention. There were two modes of arming a ship. One resembled the ancient method, when man protected himself with plate armour, which was made as thick as he could walk, or ride under. The mode at present adopted, was first to construct the ship, and then to surround it with certain defensive armour. This purely defensive armour added nothing to the strength of the ship itself. He would not assert, that the system was wrong, but it was evident, that the enormous weight of iron, with which the ship was clothed, not only did not add to the strength of the structure, but on the contrary, it created weakness in the vessel. If a steam ram were so constructed, he thought it could never bear concussion, as the plates would fly off. He doubted, therefore, whether this system of plating ships was the best; but it was a subject which was worthy of all the attention that could be bestowed upon it.

Mr. Scott Russell had alluded to the want of proper experiments, upon the power of resistance of iron plates riveted together; and in the absence of those experiments Mr. Hawkshaw ventured to submit, that it could not be expected, that the same thickness of riveted plates would resist shot, as well as solid blocks of iron. On the other hand, a ship could be constructed of riveted plates, weight for weight, much stronger than on the present system. Riveted plates could also be applied to forts. The present idea of building ships, or forts appeared to be to construct the framework first, and having done that, to cover them with iron plates. This system did not appear to be correct; he would rather desire to combine the framework and the armour plates into one mass. In a circular fort there could be no difficulty in doing this, by the proper use of riveted plates, and thus to convert the whole of the fort practically into one piece of iron, which would, for defensive purposes, be very effective, and would, he believed, turn out to be the best mode of constructing both ships and forts. He saw some difficulty in combining iron and masonry together, as, for instance, in putting iron embrasures into the stone walls of forts. He thought it would be better, in important forts, to dispense with the stone work in the front, and to introduce iron for the whole extent of the face exposed to fire; it could be made as thick as was considered necessary. Possibly the iron-face work might be backed with concrete, or masonry, but that would depend on the thickness of iron adopted and the weight of the projectile to be resisted, but he thought there could be no difficulty, in this way, in erecting a fort which, as regarded a ship's fire, would be quite impregnable.

Such were his general notions upon the mode of construction to be applied to ships and forts, and he threw them out as suggestions, for the consideration of those who had more time to bestow upon the matter, than his professional avocations permitted.

Colonel LYSONS said it would be out of place for him to make any remarks, upon the mere mechanically scientific portions of the subject. He would leave to Mr. Scott Russell, Captain Scott, and others, the discussion with regard to iron plates and the construction of ships. The general principles that should be adopted for the defence of the country, came more within the province of the military man; upon that subject he would venture to say a few words, and he would endeavour to render intelligible what appeared to him to be the common-sense view of the case.

He agreed in all the main points alluded to by Colonel Jervois; but at the same time, there were one, or two matters, regarding which he did not quite concur. He would, therefore, endeavour to place the argument in another point of view, which might be useful in enabling the question to be understood.

However improbable, or impossible such an occurrence might be, he would, for the sake of convenience in argument, suppose the case of an attack upon Great Britain, by its near neighbours. The question to be considered would then be;—whether the country should be defended by large fortifications upon land,—whether it should be defended by a powerful Channel fleet alone, —or by a combination of the two modes, and if by the latter, what proportion they should bear to each other.

He would suppose two cases:—in the first, that the English fleet had complete command of the channel, and decided superiority at sea:—in the second, that the superiority at sea was lost, and that an enemy had obtained possession of the Channel. In the first case he would admit, as Colonel Jervois very justly remarked, the enemy's fleet might evade the vigilance of the British ships, and taking advantage of a favourable opportunity, might slip past and gain the coast. There were doubtless many points, on which a landing might be effected, even by a large force; but the disembarkation of the infantry would scarcely be completed, before the British ships would have gained intelligence of the fact, would drive the enemy's fleet from the coast, and would cut off all communication between it and the force which had been landed.

Now it was evident, that a force thus left in a hostile country, without a constant supply of provisions, ammunition, and fresh men, could no more exist, beyond a few days, than a man could live in a diving-bell at the bottom of the Thames, without a constant supply of fresh air being pumped down to him. The only chance of existence for an invading force would be to push on rapidly, before there was time for the stores of provisions to be destroyed, or removed, and thus to live upon the resources of the country. The only object of a hostile force, landed under such circumstances, would be to make a dash at the capital, the possession of which would enable a so-far victorious army to treat upon advantageous terms. It was not probable that the enemy would turn aside to attack a port; for to stand still without a constant supply of provisions would be certain starvation; and it was not possible, that he could succeed if he did make the attempt, for he would not have had time to land a siege train. But even granting that he did succeed, what material advantage would he have gained? Was it likely that Englishmen would be inclined to own they were beaten, and to submit to a foreign yoke, because the enemy had gained possession of the Marine Parade at Dover, and the butt-end of a harbour of refuge which would probably not be finished for one hundred years to come? Therefore where in this case would be the use of expensive land fortifications?

He would now take a view of the second case, and would suppose,—if as Englishmen they could suppose such a thing,—that the British fleet had been defeated, and that an enemy had got the decided command of the narrow seas! That was tantamount to having made a bridge across the Channel, and the enemy could then, at his leisure, pour into this country the whole force of his vast population. Englishmen were too apt to trust to their long purses for safety. In an emergency like this, the result would depend more upon available numbers than upon money. Now in case of an invasion, there would be as much excitement on the part of the attackers, as on that of the defenders. If it were a question of the invasion of England, every able-bodied person from Calais to Montauban would volunteer to serve; and it must not be forgotten, in the calculation of numbers, that a large portion of the able-bodied men in this country would be employed in removing stores, and in aiding the sick, the aged, the women, and the children, to get away from the immediate presence of the invaders. An enemy, once landed, and having established a base, or bases, could advance a powerful army into the heart of the country, leaving on either flank a sufficient force to mask any fort that might have been constructed, and the loss of the numbers left behind for this duty, would be less felt by the invaders, than the loss of an equal number of men, shut up in the forts, to defend them, would be felt by the invaded. The enemy having gained the heart of the country, England might find herself under the disagreeable necessity of suing for peace, even before the invaders had condescended to inspect the beautiful forts, upon which so much labour and money had been expended.

Would it not then be better to devote all the energies, the means, and the talents of the nation, to the construction of such a Channel fleet as no combination of nations could match? All the defences that would be required, in addition to such a fleet, would be powerful batteries on well-selected positions, either ashore, or afloat, to defend the mouths of the naval ports; if afloat, in the shape of vessels expressly built for that purpose;—good fieldworks,—(not temporary earthworks, hastily thrown up)—but good strong fieldworks, on the land side of the naval ports;—and it was deserving of serious attention, whether a line of such works, around London, would not be advantageous. This, added to a more complete system of communication by railways, and telegraphs to all parts of, as well as round, the coast, appeared to be the best means of national defence for this kingdom.

Captain W. S. Moorsom said it must be remembered that the question of the National Defences of the United Kingdom was not by any means a new subject of discussion. Mr. Burke, in speaking on the army estimates, in 1790, said "France, by the mere circumstance of its proximity, has been, and to a degree always must be, an object of our vigilance, either with regard to her actual power, or to her influence and example." Now it was necessary to consider some facts, as to how this country stood with its neighbours, in relative position as a naval power. The Navy List of Great Britain contained the names of 652 vessels of war, of which about 305 were afloat in commission. As far as mere enumeration was concerned, this considerably exceeded the number of war vessels possessed by any other nation. Again, as to war vessels of a large class available for immediate service:—

	Line-of-battle Ships.		Heavy Frigates.
Great Britain possessed about . .	33	and . .	23
Russia possessed about	19	„ . .	18
France possessed about	37	„ . .	20

Of available seamen:—

	Sailors.		Marines.
Great Britain had about	50,000	and .	18,000
France had about	35,000	„ .	20,000

and Russia had any number of landsmen, who occasionally served afloat, and became seamen at the will of the Autocrat.

In extent of coast with a population accustomed to sea-going habits:—

Great Britain possessed about .	5,200	miles in length.
France possessed about	1,550	„
Russia possessed about . . .	5,000	„

including her Asiatic shores, with a very slight sprinkling of sea-going population; in fact, her only reliable seamen were those of the shores of the Baltic.

The British power at sea, and of recruiting for sea defence, preponderated greatly over the like relative capabilities of any other nation. It seemed, therefore, that Great Britain should devote its chief energies to making its maritime power unassailable by any enemy with a chance of success, especially as this power was equally important for the security of the colonial possessions. Hence an additional reason why the navy should be made, as it were, the pivot point, or groundwork of the national system of defence.

Contrasting this with any system which would make the army, or the fortified posts on land to be the groundwork of a system of national defence, and where would the nation be? It followed, then, that for ships, and seamen, there must be arsenals of construction, repair, and maintenance. It would seem to be the opinions of a majority of the authorities, as given in the Report of the Defence Commission, that these arsenals must be protected by enormous works of defence, estimated to cost £12,000,000. The plea for this expenditure was to secure them from distant bombardment. Now this appeared to be a grievous mistake. There were several instances in war history, of arsenals held by an invading enemy, but held unsuccessfully although strongly fortified. It would suffice to quote two of these instances. Calais in the sixteenth century, and Toulon in the eighteenth century; both held by all the power of England, but they fell before comparatively undisciplined forces. There was not any instance of an invading enemy succeeding on the large scale, until after he had secured the command of the sea, which conveyed him to the scene of contest. The invasion of William the Norman was a marked and signal instance of extraordinary concurrence of accidents diverting the Saxon forces, and of extraordinary good fortune of weather in favour of the Normans at the critical moment, and this exception went rather to prove the rule. England did not attempt her land expeditions during the wars of Marlborough, and down to the present time, till she had cleared the respective seas of the enemy's vessels. The battle of the Nile cleared the way to Alexandria; that of Trafalgar cleared the way for the invasion of Portugal and Spain. The Black Sea was commanded by the allied men-of-war, before any attempt was made to start from Varna.

While the British fleet held the command of the Channel, there need not be any apprehension of an invasion on a large scale. Colonel Adair had remarked that the fleet "had been baffled before, and might be baffled again;" but he had not shown, that even from this baffling any ill consequences followed. If an invasion, on the large scale, were a small thing in itself, some danger might arise from the fleet being sent to Cape Clear when it ought to be off Beachy Head. But, what were the preparations for such an invasion which acted as plain warnings? When France invaded Algiers, in 1830, she had cleared the coasts of Algerine cruisers, and had accumulated 570 vessels to convey the expedition across the Mediterranean. When the combined forces of England and France sailed from Varna, they occupied 700 vessels. The only invasion of England that had been threatened for centuries required such numerous vessels, that their whereabouts and force were well-known long before they were ready. Was Great Britain less capable of preparation now, than then? When invasion was seriously meant, it would be well known beforehand; as also whereabouts the blow must fall.

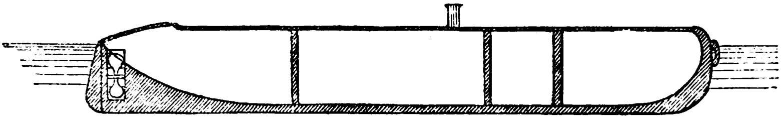
Captain Moorsom did not mean that the present defences of the arsenals were not needed, in order to secure them from some sudden *coup de main;* but he would add to those at present in use, only such isolated defences as might keep off insults from the seaboard, as contradistinguished from the expenditure of £12,000,000, to convert these arsenals into standing camps of the weakest kind; too far advanced to be camps of reserve; too distant from the great centres of population to be rapidly manned by organised bodies of defenders, and lastly, if so manned, then absorbing armies sufficiently large to act with better effect in the field.

Henceforward the character of the present arsenals ought to be changed. Every Engineer knew the difference between the fitting-shop and the factory. The arsenals, on the seaboard, should comprise only the fitting-shops; each to supply the necessities of a port. The factories for the supply of armament and large renewals, should be inland, and be defended only like the hearths and the homes of the country, by that national personal defence which would never fail among Englishmen.

If this view of the subject were taken, it should at all events cause an economy of some ten out of the twelve millions, and this saving might be applied to seaboard defences. These latter defences should consist in improved ships, and a more popular method of manning them; and also in a system of arrangement of the land forces, corresponding with these improvements and with the existing extraordinary means of internal transport. On this point it was allowable to feel pride in what the Civil Engineers of England had done for the advancement of the practical defences of the nation. Looking at the 'Himalaya' as a transport,—the Thorneycroft embrasure,—the Armstrong gun,—the Whitworth rifle,—the appliances of Blakely, Cowper Coles, Jones, and a dozen others that might be named, every one must see that National Defence owed much to the Civil Engineers; but few comparatively knew how much difficulty was met with, in thus becoming as it were a creditor of Britannia. Captain Moorsom would relate one instance, and he had heard of more such. In October 1854, after a good deal of study, he presented to a Lord of the Admiralty, well known as a good seaman, the plans and description of a vessel to run into the harbour of Sebastopol, and to destroy the 'Vladimir,' and some other Russian ships then afloat, which were doing the besiegers at that time most serious injury. In December, 1854, this Lord requested him to meet Sir Baldwin Walker and Mr. Lloyd, which, after some more delay, was accomplished. They told him they would report that the details of the invention ought to be tried; and on the 10th of January, 1855, he was desired to lay it before the First Lord as a secret invention. On the 15th of January, the First Lord's secretary desired him to lay the matter before the Board of Admiralty: the receipt was acknowledged on the 18th of January, and after two inquiries as to its progress, he was officially informed that the plans had been lost, and no copy had been taken! On being subsequently shown the invention, Admiral Lyons asked with the utmost eagerness why it had not been "brought out" before? and the inference was, that he saw its practical value.

Captain Moorsom exhibited a section of a shot-proof boat, (Fig. 1), which might be made available for the defence of harbours and the destruction of an enemy's vessels attempting to enter, or lying within them.

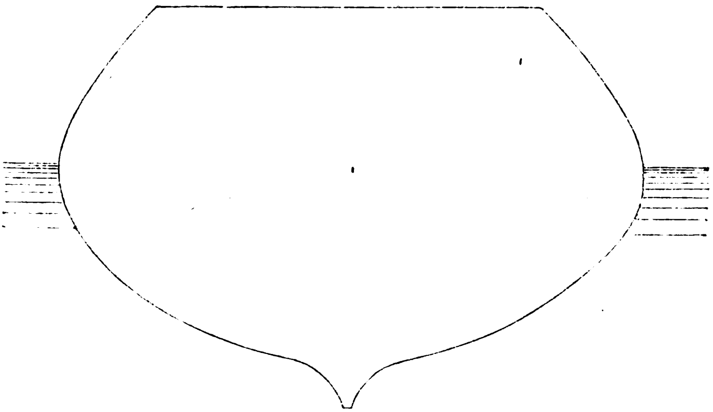
Fig. 1.



Longitudinal Section of Shot-Proof Boat for Harbours.

Now, as to the construction of an iron fleet, he did not think that plating vessels with iron was the best mode of construction. The frame and plate should rather be so combined, that each gave mutual and reciprocal bracing, strength, and protection; the system of compartments and bulkheads being also adopted, to insure floatation when the outer casing was injured. It had been stated in the paper that "armour of 5-inch iron must greatly impair the efficiency" by reason of its additional weight. Weight of armour, or of casing, of a vessel was entirely relative to the capacity of the vessel. A familiar illustration occurred in the hard thick shell of the cocoa nut as compared with the thick-shelled walnut. The cocoa nut, although the thicker of the two, was much more buoyant, owing to its relative capacity over that of the walnut. So with iron ships, their sides might be made invulnerable to shot, partly by thickness and quality of metal, and partly by the proper curvilinear forms given to the exposed parts of the vessel, and these forms added to the cupola shield would make a vessel practically invulnerable if properly constructed.

Fig. 2.



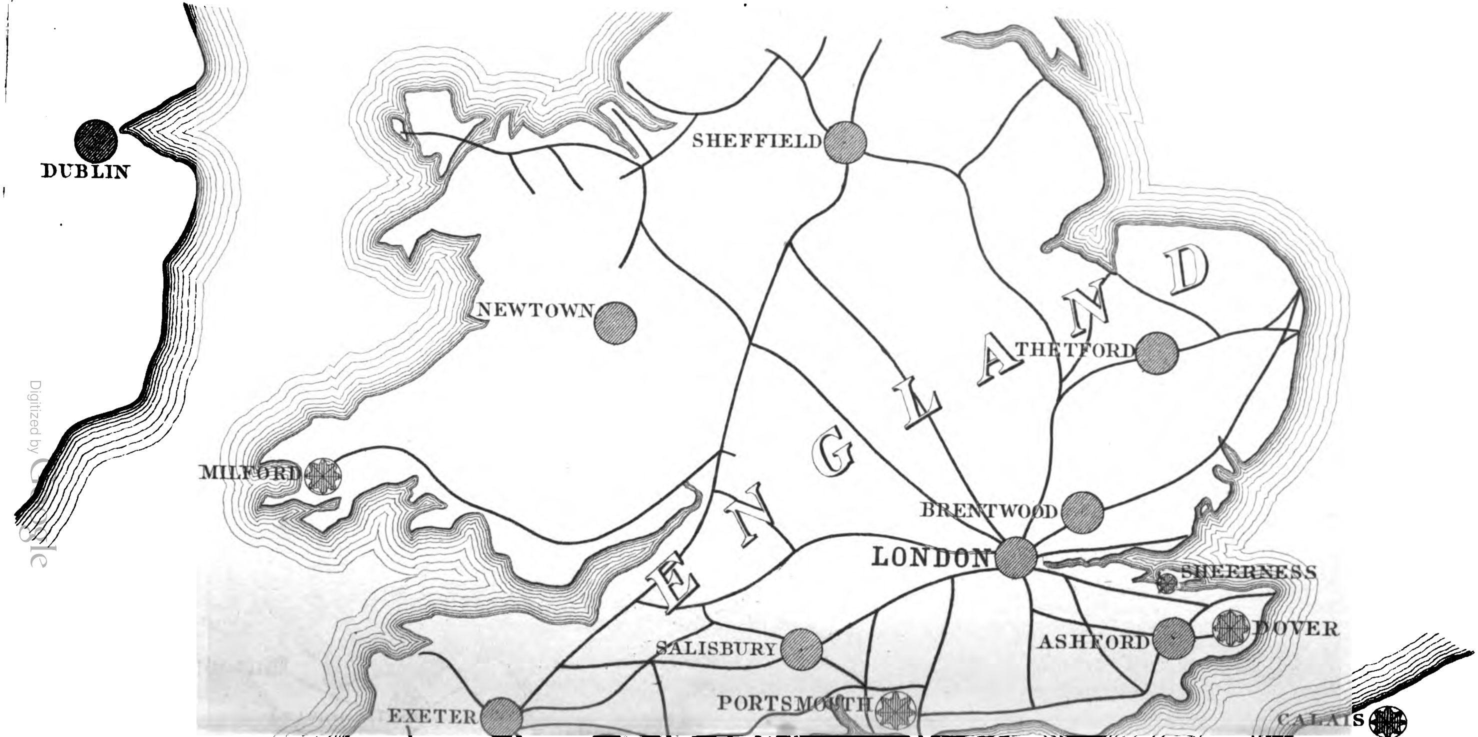
Midship Section of Shot-proof Ship.

The displacement as well as the capacity or tonnage of such vessels must be enormous. It was hardly possible to give them speed, stability, and buoyancy with less than 7,000 tons burthen. Such vessels, however, would be the future line-of-battle ships; and the services other than fighting in line or in mass might be performed by vessels of other classes and of less tonnage, though not of slighter construction, such as had been adverted to by Mr. Samuda.

Next as to land defences. In 1853, when practice was made from the 'Excellent,' in Portsmouth Harbour, with shot and shell against the then existing iron vessels, the hollow shot which he exhibited, was presented to him, as a fair sample of the general effect upon such shot, when striking the comparatively thin iron plates of that day; which plates were smashed in by the blow. The examination of this shot led him to the conclusion, in 1853, that the best revetments, for situations where breaching and escalade were to be guarded against, would be of iron. He was requested, by Lord Hardinge, to lay the subject before the Master General of the Ordnance, but foreseeing only a mass of delays and difficulties, he declined doing so. There was, no doubt, that for situations where breaching, prior to escalade was necessary, it would be indispensable to resort eventually to iron, in order to form a perfect revetment. In this there was a very fair opening for the Civil Engineers to be dealt with on a system of reciprocity. The civil railroads were examined by Royal Engineer Colonels, and the mercantile steam-boats were surveyed by Naval

NATIONAL DEFENCES.

PLATE 6, VOL. XXI.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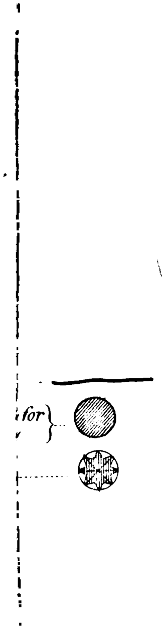

STLE ST. HOLBORN.

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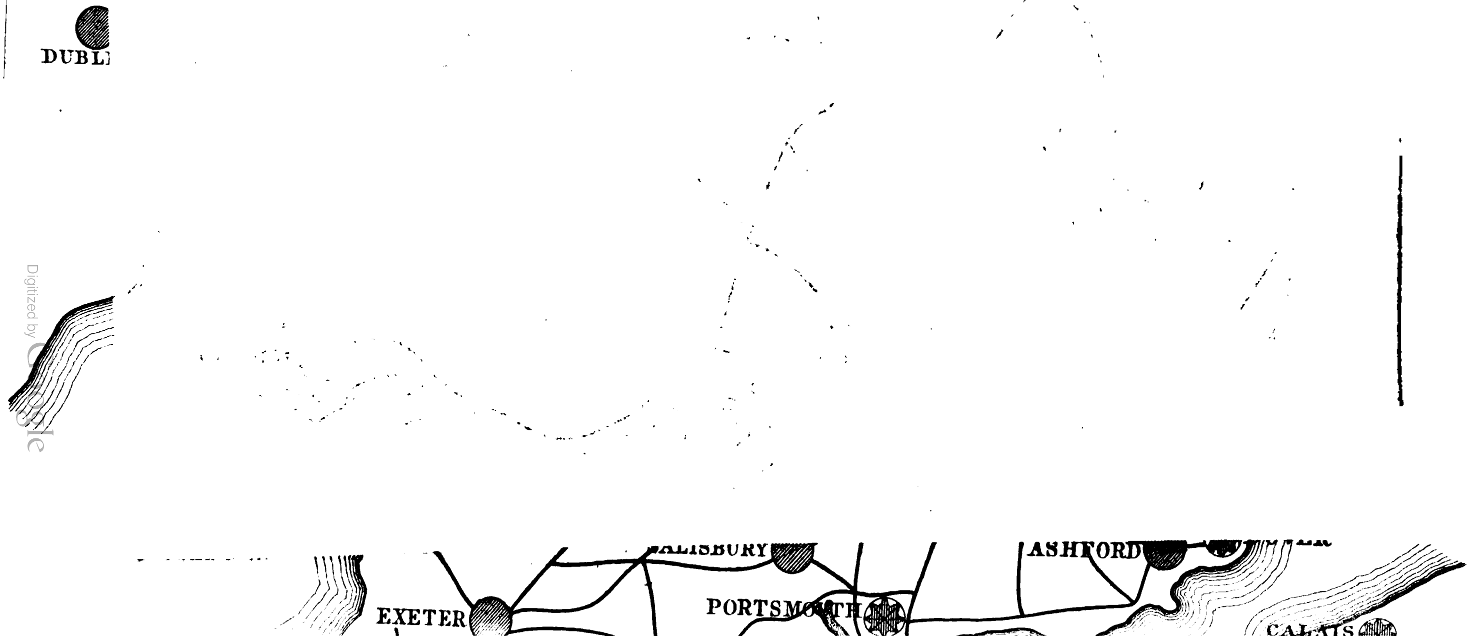
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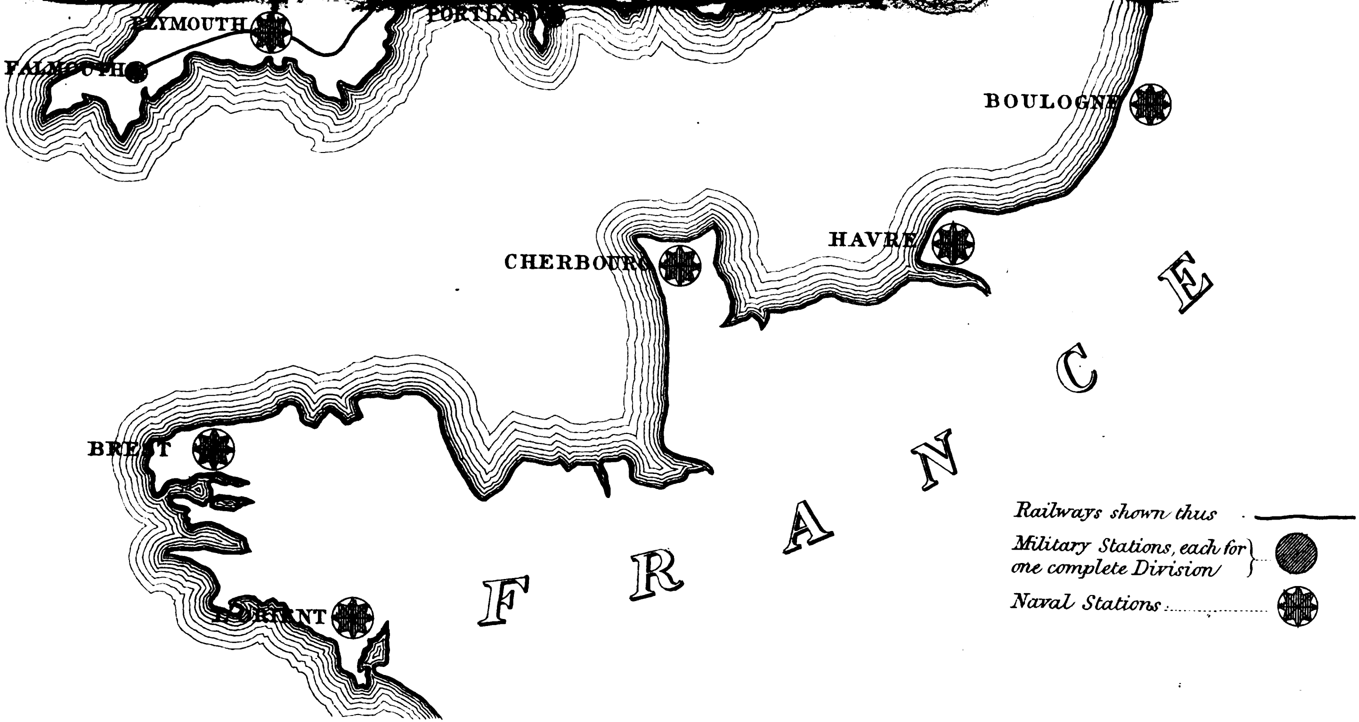

PLYMOUTH
FALMOUTH
PORTLAND
BOULOGNE
CHERBOURG
HAVRE
BREST
LORIENT
FRANCE
Railways shown thus
Military Stations, each for one complete Division
Naval Stations

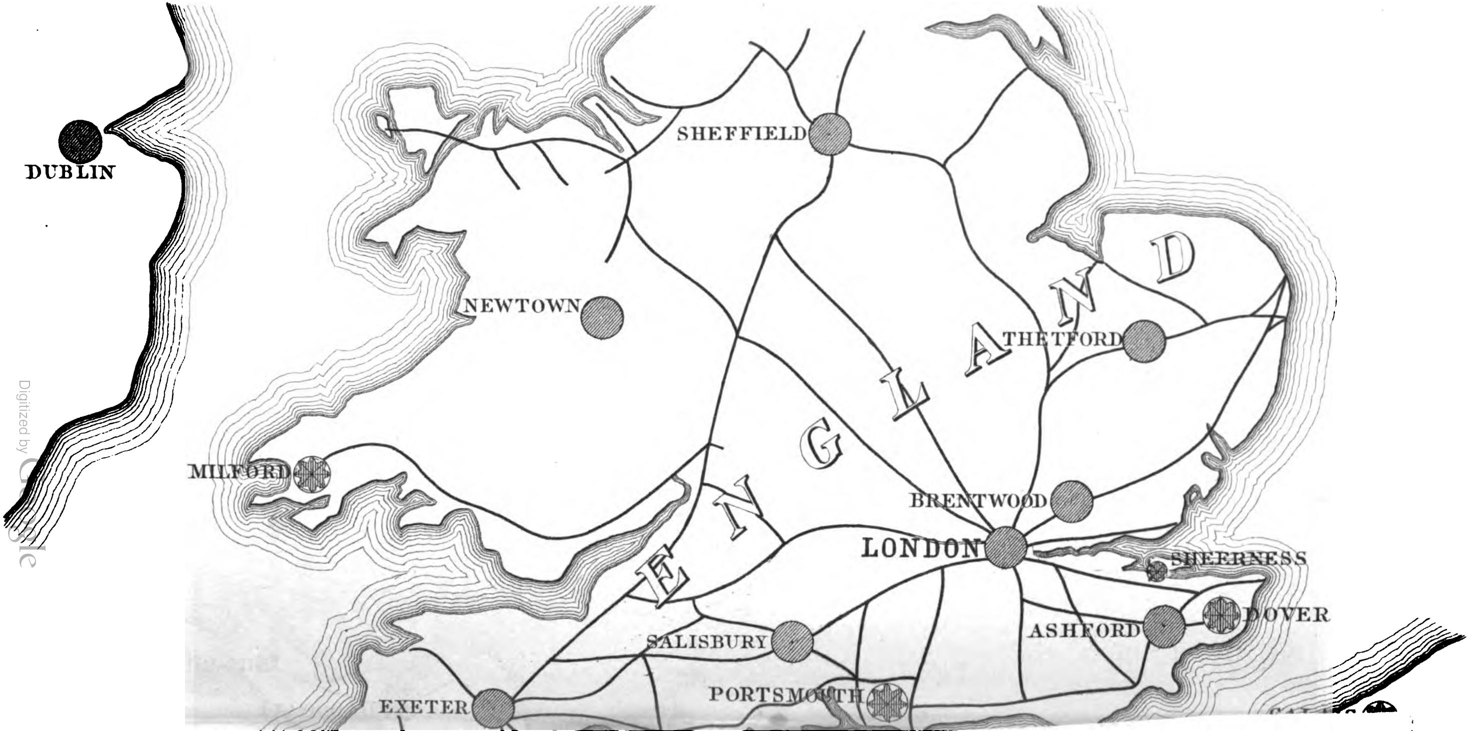
Minutes of Proceedings, Institution of Civil Engineers Vol. XX. Session 1860_61

W. S. MOORSOM, DEL^T

KELL BROS. LITH^RS CASTLE ST. HOLBORN.

PLATE 6, VOL. XXI.

NATIONAL DEFENCES.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SHEERNESS
DOVER
ASHFORD
SALISBURY
PORTSMOUTH
EXETER

HOLBORN.

W. S. MOOI

Captains. Why should not the forts and the constructive works in the arsenals be systematically inspected by Civil Engineers? If there was little public good arising from the system of gentlemen inspecting works, whose previous habits did not fit them for the task, there was, at least, equity in the parallel. But the designs for, and the superintendence of, the foundations required for all the sea-board works might be placed in the charge of experienced Civil Engineers, with great economy and advantage to the public service.

Next with regard to the general system of national defence; he had already said, that the land defences should be limited to preserving the country from insult, and from sudden descents on points of value, such as the arsenals. The additional forts which might be requisite for such preservation, would be best constructed of iron, in the form of martello towers and with cupola covers against vertical fire, as contradistinguished from forts on the 'polygonal system,' which, if he understood it rightly, was nothing more than a series of improved redoubts; and if so, he did not see what was to prevent a well-supplied enemy from raining a vertical fire upon such a fort till he made it too hot to hold the garrison, as had lately been seen in Fort Sumpter,—a fort built by those whom the 'Charlestown Courier' called "the most accomplished Engineer Officers in the world." But, if ever the battle was to be fought on the soil of England, the best defence would be the trained troops in the field; and to this effect the present regular forces which were now said to amount in Great Britain and Ireland to from sixty to eighty thousand men should be organised in war divisions of from six to eight thousand men each, of the three arms. Standing camps should be established, if not permanently, at least from the middle of April to the middle of October, in the best positions. Each division should be complete in itself, and should be trained as such, and occasionally and systematically two divisions, forming a *corps d'armée*, should be concentrated on certain points of the coast, to practise them in repelling attack. The volunteers should be attached systematically, according to their local organisation, to these divisions; and the garrison artillery, marines, and police would still be available for the ordinary duties of the dockyards, when those services should be properly reduced to the necessary standard of local duties. Plate 5, showing the best positions for concentrating these divisions, explained this.

Thus with the fleet efficiently constructed, as had been adverted to, there need not be any fear of invasion on the large scale. And if invasion were attempted on the small scale, there would be that defence of the hearths and the homes,—namely, the stout hearts and hands of the people, which best befitted the character of Englishmen.

Mr. Conybeare said, the question raised by the Paper fell naturally under two principal heads. First, what were the conditions of maximum efficiency, in respect to material, size, and design, to be fulfilled by the vessels composing the Channel fleet, constituting the first line of the national defence? And secondly, whether, taking into consideration the increased powers of the attack, due to the recent introduction of mail-clad ships-of-war and long-range ordnance, it was possible, and if so, by what means, so to fortify the naval arsenals and other positions along the seaboard, as to render them a secure base of operations for the Channel fleet, and to form to some extent a second line of defence?

The screw liners, forming the present line of battle of all European navies, were introduced and designed with the object of obtaining the advantages of steam propulsion, without any sacrifice of the sailing and fighting capabilities of the vessel, or any increase of its vulnerability, and these objects had been partially attained, by substituting the screw for the paddle-wheel, and placing the machinery sufficiently below the water level, to be somewhat beyond the reach of shot. This was of paramount importance, for it was manifest, that a vessel, whose machinery was crippled in action, would be utterly at the mercy of any other ship, which preserved its power of locomotion unimpaired.

These screw liners having been only recently introduced, had scarcely yet been tried in actual naval warfare; but they possessed certain defects as men-of-war, which were too palpable to require an experimental demonstration. The first of these defects related to the material of the vessel. It was now generally admitted, that no timber-built ship could endure, for many minutes, a close cannonade from the shell guns and heavy metal, which had been introduced into naval armaments, since the last war. This defect was now being remedied, by the substitution of iron-plated vessels, for those of timber; of these the 'Gloire' and the 'Warrior,' were the two most recent types, and the former had been found, on trial, to fulfil the necessary conditions of a line-of-battle ship, so much more completely than anything previously constructed, that there could not be any doubt of all future armed vessels, intended for the line of battle, being iron-plated.

Engineers appeared to be agreed, that all future vessels of war should be built entirely of iron, instead of being merely plated like the 'Gloire;' because iron vessels were indestructible by fire, and withstood the excessive strain and shocks of the machinery, infinitely better than those built of wood, and were in all respects much stronger. They moreover possessed greater internal capacity, for the same displacement, and required incalculably less repair and renovation than those of timber: this last advantage was of paramount importance, if the statement was correct, that of the twenty-nine millions sterling, expended during the last eight years, on the maintenance and reconstruction of the navy, upwards of twenty millions had been expended on repairs, alterations, and renovations, and only eight millions on new ships!

The second defect of the screw liners was the liability of their funnels to be breached between decks, by a shell entering one of the portholes, and exploding within the funnel; the smoke escaping from such breaches would probably drive the men from their guns, or the vessel might be crippled by the necessity of damping the fires. This defect was somewhat obviated in iron-plated ships, but it could only be completely removed, by substituting a mechanically urged draught, for the chimney draught, and a horizontal and consequently a completely protected funnel, having its vent close upon, or below the water line, for the vertical unprotected tube, which at present disfigured all steamers, and so materially detracted from the efficiency of war steamers. The practicability of substituting horizontal, for vertical funnels, had been established by the use of such a funnel, for many years past, in the American steam frigate 'Princeton,' and it was manifest that the saving in space and the incombustibility of the skin, due to the substitution of iron for timber, in the sides of the vessel, afforded much greater facilities for such an arrangement, than were obtainable in the case of the 'Princeton,' which was built of timber.

The third defect of screw liners, was the tendency of the screw to draw into its vortex, any wreck floating in its vicinity, by which it became entangled and disabled. In a closely-contested action, such fouling of the screw, in the fragments of the rigging, shot away and towing astern, or floating unattached, would be almost inevitable, and with the screw, so fouled, the vessel would become an unmanageable hulk, and be at the mercy of any assailant that preserved its power of locomotion unimpaired. No screw vessel could be really perfect as a man-of-war, in which this contingency was not guarded against, by providing a supplementary mode of propulsion, which might be resorted to, in case of the screw becoming fouled, and so temporarily disabled, and which would enable the vessel to be moved and manœuvred, at least at the very moderate speed that would suffice in such closely-contested actions, as those in which such an accident as the fouling of the screw would be most likely to occur. The most handy method of obtaining such supplemental means of propulsion, would be by the reaction of currents of air, or of water, expelled by means of pumps, worked by the engine, and thrown into gear, whenever the screw became fouled; from these pumps, four wrought-iron mains disposed like the letter X, should be extended through the sides of the vessel, and terminating in four nozzles, two pointing ahead and two astern; the water, or air, being expelled by the pumps, in a continuous stream simultaneously, through any two of the four orifices. If expelled through the two pointing astern, the vessel would move ahead, and if through the two nozzles pointing ahead, she would move astern, and by expelling the current simultaneously through the forward starboard and the aft larboard, or *vice versâ*, the vessel could be turned on the spot, swinging on her beam, without the aid of a rudder, and much more rapidly than by the rudder. Indeed the facility of this mode of manœuvring in close action, would be so great, that it was very probable, that men-of-war, provided with such supplemental means of propulsion, would, on coming into action, lift up the screw out of harm's way, and would use their supplementary motive power as their fighting gear. It was not necessary to take up the time of the Meeting, by giving the details of such an apparatus, as both the pneumatic and the hydraulic modes of propulsion, had been already practically tested by the water propeller of 'Ruthven,' before described in the "Minutes of Proceedings,"[1] and the air propeller of 'Carter.' Though neither had proved on trial so economical a mode of propulsion as the screw, there could be no question, but that they were perfectly adequate and well adapted to the supplemental uses to which it was proposed to apply them; and if any objection should be founded on the amount of space that they would occupy, it might be assumed, that more than the additional space required might be gained by building the vessel of iron instead of wood.

On instituting a comparison between the 'Gloire' and the 'Warrior,' it appeared, that the former was less vulnerable and more formidable, in proportion to her cost, than the latter. The 'Warrior' was twice as large as the 'Gloire' and had cost twice as much, yet she carried fewer guns, only twenty-six protected, against the 'Gloire's thirty-six guns; the 'Gloire' was entirely shot-proof throughout, whereas the 'Warrior' was only shot-proof for half her length, (205 feet out of 420 feet); the 'Gloire' was lightly rigged as a three-masted schooner, the 'Warrior' had the masts and rigging of an eighty-gun ship, and owing to the relative areas of the targets presented by their rigging, the chances of the screw being disabled by fouling in the rigging shot away, and being towed astern, was three, or four times greater, in the 'Warrior' than in the 'Gloire,' and supposing either to be so disabled, the under-water projection of the prow of the 'Gloire' would enable her to finish the combat, by staving in the side of her antagonist, below the water line, in a way that would be impracticable with the projecting cut-water of the 'Warrior.'

Though the 'Warrior' had cost twice as much as the 'Gloire,' nobody believed that two 'Gloires' would not be far more than a match for the 'Warrior,' and there was even abundant reason for believing, (taking into consideration the novel conditions of a conflict between two iron-plated ships), that in single combat, the 'Gloire' would be able to beat and sink the 'Warrior.' A duel between two iron-plated vessels would resemble those in the Roman amphitheatre, in which one of the gladiators being armed with a casting-net and three-pointed spear, first endeavoured to cripple his adversary, by lassoing him with his net, and when he had thus rendered him incapable of motion, finished the affair by poking him under the ribs with his weapon. In like manner, when two iron-plated combatants got in sight of each other, the first endeavour of each would be to shoot away the rigging of her adversary, in hopes that it might foul the screw, and so render her unmanageable. Now in this phase of the conflict the 'Gloire' would have an enormous advantage over the 'Warrior;' for she had ten more guns and three times as large a target of rigging to fire at. If notwithstanding these triple odds against her, the 'Warrior' was so fortunate as to range up alongside the 'Gloire,' with her screw in an efficient state, she would still labour under immense disadvantages. As compared with her opponent as regarded power of offence, of defence, and of mobility, she would have only twenty-six guns to her adversary's thirty-six; she would be only protected for half her length, when her opponent would be wholly protected, and being twice the length of her adversary, she would be four times as difficult to turn and manœuvre; and all she would have to fire at would be the iron-plated sides of her adversary, whereas the 'Gloire,' by concentrating her fire on the unprotected stern of the 'Warrior,' could hardly fail to cripple her screw. The 'Gloire' was little more than half the length of the 'Warrior,' and in close combat, the comparative handiness of the 'Gloire' in turning, would enable her to take and to keep the most advantageous position for attacking the vulnerable points of her unwieldy antagonist. Supposing the screw of the 'Warrior' to be once crippled, the 'Gloire' gaining a position on her flank, and charging her amid-ship, would crush in her side below the water mark and sink her. There could be no doubt, that every steel-plated frigate should have her prow so formed, as to enable her to finish a crippled antagonist, by crushing in her side, below the water line; in fact there was scarcely any other method of terminating a duel between two iron-plated vessels. It would be a waste of ammunition for either to hammer away at the shot-proof sides of the other. Boarding was entirely out of the question when all communication between the fighting deck and the spar deck could be cut off, and with iron block houses fore and aft sweeping with their fire, the only deck to which boarders could obtain access. But it seemed inexpedient to construct any special class of vessel to be used primarily as steam rams, unless it were on a small scale for the defence of harbours, in which case, the steam ram proposed by Mr. Nasmyth would probably be the best type to follow.

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[1] *Vide* Minutes of Proceedings Inst. C. E., vol. xiii. p. 370.

He agreed with the Author of the Paper, that in iron-plated vessels, the spars and rigging should be of the lightest possible description; probably a latteen rig would be found to combine more advantages than any other.

In action, the primary essentials of an iron-plated liner, would be, 1st, A powerful offensive armament;—2nd, Complete defensive armour;—3rd, Mobility, or facility of turning, and of changing position rapidly;—and 4th, As high a rate of speed as could be attained, without detracting too much from the first three essentials. The 'Warrior' was palpably inferior to the 'Gloire' in power of offence, of defence, and of mobility; instead of being wholly protected, she was only half protected,—she had ten guns less, had no power of acting as a ram, and she required more than twice the time and space to turn in. But Mr. Scott Russell said that she would steam 14 knots to the 'Gloire's' 12 knots. The question therefore arose, whether the extra 2 knots of speed was not purchased too dearly, by so large a sacrifice of the other essentials of a line-of-battle ship, and by far more than doubling the cost of the vessel per gun. To gain an increase in speed of only 16 per cent. the cost of the vessel was increased 100 per cent.; her armament was decreased 30 per cent., and her defensive power and mobility each 50 per cent. It might be of paramount importance to a cruiser, to be able to go 14 knots an hour instead of 12 knots; but high speed was by no means the first essential for the line of battle, and it could only be attained by the sacrifice of other and more important qualifications. The speed at which the naval line-of-battle manœuvred must be limited by that of the slowest ship it contained, and as high speed could only be attained by the sacrifice of other and more important qualifications, it was not probable, that vessels, in line of battle, would ever manœuvre at a greater speed, than that of the 'Gloire,' or at 12 knots an hour. Sir Howard Douglas had shown, that the adoption of steam propulsion, by line-of-battle ships, had assimilated the system of manœuvres of a line-of-battle at sea to that of a line-of-battle on shore; a steam liner being the unit in the naval line of battle, as the battalion was the unit in a line of battle on shore. Experience had shown, that on land, mobility was sacrificed by increasing the strength of either a company, or a battalion, beyond a certain limit. The same rule applied to the units of a naval line of battle, and it was obvious, that in a change of formation, in presence of the enemy, the whole line might be thrown into confusion, by some of the liners taking twice as much time and space to turn in, as the others did, owing to their unwieldy length. It was therefore desirable, that all the ships of a line of battle should be equal in speed, size, and power of turning, and that as an increase in size implied a decrease of mobility, there was a limit in size, which it was not expedient to exceed. Financial considerations, also, imposed a practical limit to the cost per gun, for it was obvious, that in naval warfare, with so many points to defend, and such an immense field of operation to cover, it was more advantageous to expend the amount for naval constructions, in building a large number of moderate-sized vessels, than in constructing a small number of monster steamers.

It would appear that all this had been carefully considered, in determining the size and general design of the 'Gloire.' The French had previously come to the conclusion, that all the vessels of the line of battle, should be of moderate and uniform size. They had increased the size of their vessels, till they had the heaviest three-deckers in the world; but they found, by experience, that three-deckers were far more costly, in proportion to their force and efficiency, than vessels of two decks; they consequently discontinued the building of three-deckers, and resolved, that all future liners should be two-deckers of uniform size, on the model of the 'Napoléon.' The 'Gloire' was of the same tonnage as the 'Napoléon,' and was said to be built on the same lines, and it would appear, that this size had been adopted, after careful consideration, as that model was considered to be best adapted to produce the maximum efficiency, for a given outlay.

The French had always excelled in the art of designing vessels of war, and their designs were so scientifically elaborated, that years elapsed before even their first models were superseded. In the great war, all the best vessels in the British navy were either French prizes, or were built on French models. The 'Canopus,' which was taken from the French, at the battle of the Nile, in 1798, was still in active service, forty years afterwards, and even then was esteemed, by many high authorities, as the best model of a line-of-battle ship in the navy; and similarly, though the 'Napoléon' was one of the two first screw liners launched, she was still esteemed the best model of that class of vessel extant.

The 'Gloire' had been designed, with equal consideration, and she would prove as hard to be surpassed as the 'Napoléon.'

It would appear, that the wisest thing the Admiralty could do, would be to profit by past experience, and to build a vessel nearly resembling the 'Gloire,' only substituting iron for timber, for the substratum; such a vessel would, at any rate, be a serviceable man-of-war, instead of being a fancy article, like the 'Warrior,' and by experimenting upon her, she might be made a point of departure for further improvements. This would not be difficult, and the Government must be much worse served than was generally believed, if it was not in possession, long since, of the working drawings of all the French plated men-of-war.

Mr. Scott Russell had blamed the Admiralty, for attempting to build iron-plated vessels on so small a scale as the 'Gloire,' and especially for importing economical considerations into the problem, by requiring that the cost of such a vessel should not exceed a given amount per gun. Mr. Conybeare must differ from Mr. Scott Russell on this point, as he thought it was very much to the credit of the Admiralty, that they should have taken such a practical and business-like view of the requirements of the situation. It was obvious, that the 'Warrior's' type did not fulfil these requirements; her means of offence and defence were flagrantly disproportionate to her cost and tonnage. Considerations of economy were never disregarded, except by visionaries; and even were the 'Warrior' an efficient man-of-war, no Government could afford to build a sufficient number of such costly vessels. The sums voted for building vessels of war were limited in amount, and the money must be made to go as far as possible, in the number of vessels built, as well as in the number of guns mounted afloat. Now excluding block ships, iron-plated vessels, and small craft, the actual naval force was only just equal to that of the French. As regarded the number of ships, of guns, and of horse-power, Great Britain had now afloat and building, in line-of-battle ships and frigates, 84 vessels, carrying 5,974 guns and of 47,740 H.P.; and the French had 86 men-of-war and frigates afloat and building, carrying 5,294 guns and of 46,890 H.P. So far the forces of the two countries might be considered practically equal; but the French had the start in iron-plated vessels, and as the Imperial Commission observed:—"Supposing a large numerical superiority to exist on the side of the English, it would be more than counterbalanced by the multitude of objects to defend against possible attacks, amongst which their forces must be divided." It would be remembered, that during the war which commenced in 1793, whenever the opposed fleets met, the superiority of numbers was on the side of France, and yet England had then 145 ships of the line, while France had but 77 ships. In fact, in order to oppose an equal number of vessels to those of the French, in a Channel fight, the English navy must possess two vessels to their one.

Under such circumstances, and with twice as large a navy to construct, it was palpable that England could not afford to pay for their naval force, two or three times as much per ship and per gun as the French, and that therefore only such vessels should be built, as were really serviceable either as ships of the line, or as cruisers. The 'Warrior' was not adapted for either purpose; she was too large and costly for a cruiser, and her deficiency in power of offence, of defence, and of mobility unfitted her for the line of battle. If the money she had cost had been spent in the conversion of the actual three-deckers into iron-plated frigates, (for the decks and rigging removed, in such conversion, would exceed the weight of the plating added,) the country would have the advantage of the French in plated frigates.

The Government had been much abused, by inventors and reformers, for having allowed the French to take the initiative in the introduction of steam liners, of iron-plated men-of-war, and of rifled ordnance; but it would be impolitic, for a power situated as England was, to have taken such an initiative. As long as men-of-war were only propelled by sails, the fact of England having three, or four times as many sailors and twice as many sailing vessels as France, insured its naval superiority; and it was clearly not good policy to disturb a state of things so advantageous to this country; but the introduction, by the French, of steam liners, and of iron-plated frigates, had turned the balance the other way. The French writers now exulted in the fact, that the functions formerly discharged by sailors, on board vessels of war, would in future, be performed by the engineers and stokers; that in fighting the guns, soldiers, trained as artillerymen, would be at least as efficient as sailors, if not more so; that as they would be able to organise a larger force of marine artillery than England, the superiority would henceforth be with them; that as owing to the far greater number of points England would have to defend, there would be required at least double as large a fleet as the French, to be equally strong in the Channel; and that the reconstruction of the fleet, in iron, would thus be a more serious burden to England than it would be to France. Similarly, as regarded rifled ordnance, a gallant officer had stated, that the nation possessed a stock in hand of smooth-bore ordnance worth ten millions of money, and the introduction of rifled ordnance had rendered this large amount of material valueless, save as old metal.

When once, however, the initiative had been taken by the French, it became incumbent on the British Government to follow promptly and to overtake them, with all the means which the superiority in manufacturing resources placed at their disposal; taking, if needful, the most recent French models as the point of departure, and trying only to build on a ready-made foundation, by improving upon them, instead of wasting time and money, in experimenting, as had been done in the case of the 'Warrior,' and in the attempt to arm the navy with heavy breech-loading guns.

The result of these misdirected efforts was, that the service was still without a serviceable iron-plated vessel, or a powerful gun for navy, or coast defence, though enough money had been spent in futile experiments to have supplied the country with both.

It had been argued, that the fortification of the arsenals might be dispensed with, first, because the Channel fleet ought to suffice for keeping an enemy from the coast; and, secondly, because fortifications could not be constructed, which would be proof against the iron-plated war-ships and long-range ordnance of the present day. Now it appeared to Mr. Conybeare, that as regarded the Channel fleet, it could not be divided, in time of war, in the face of an enemy, who could select its own point for a concentrated attack, without exposing the English force to the certainty of being beaten in detail. Portsmouth must henceforth be the head-quarters and principal repairing and coaling depôt of the Channel fleet, in time of war, and the length of open-coast line, liable to attack, was so great, as, compared with the width of the strait, that a French force might be landed in the Thames, or at Bristol, forty-eight hours before the Channel fleet could reach the point of debarkation. The Channel fleet might avenge, but could not prevent a descent of the enemy; and if the immense destruction of property, that might be caused by a single iron-plated vessel of the enemy slipping into an undefended harbour, and setting fire to everything combustible within range of its shells, were considered, it was manifest, that if the national property was to be secured, the naval arsenals and the principal harbours must be rendered proof, at least against a *coup de main*, either by land, or sea.

The introduction of steam propulsion had rendered the fleets infinitely more dependent on the arsenals, for supplies and for repairs, than was formerly the case. A fleet of sailing men-of-war might cruise for months together, without standing in need of putting into a naval arsenal, either for supplies, or for repairs; whereas a modern fleet, propelled by steam, could not cruise for as many days, without requiring a fresh supply of fuel, without which it would be paralysed, would be incapable of attack, or defence, and be exposed to certain destruction, if attacked. A steam fleet, without a secured base of operations, was powerless; and the first essential to success, in a naval war, would be to render the naval arsenals equal to any emergency, for the supply and repair of as many vessels, as might stand in need of either coaling, refitting, or repair, after a cruise, or an action with the enemy.

The French appeared to have gained a great start in this respect. Cherbourg was intended, not as a building-yard, but to be, in the event of war, the central depôt and base of operations of France, in the Channel, by means of which the Channel fleet might be constantly "sustained in activity and efficiency, by the "means there organised and prepared, for supplying and repairing "them;" and Portsmouth must be to the English Channel fleet, all that Cherbourg was to that of the French.

The basins at Cherbourg included 48 acres of deep water, which the largest ships, armed and ready for battle, could enter and depart from, every day in the year; and six large docks, (two being double docks, each capable of receiving two ships,) opened out of the basins, and were at all times accessible.

The basins of Toulon would, when finished, comprise upwards of 80 acres.

The harbour of Brest formed one great natural basin, having quays of considerable extent on its shores, alongside of which the largest ship could lie; but in addition to these great natural resources, five artificial basins were in course of excavation.

The two basins at Portsmouth, on the other hand, comprised 9½ acres, or less than one-fifth part of the area of the basins at Cherbourg, "but their value, in comparison, was far less than a fifth, for from their shallowness, they could not be opened, except during spring tides, and even then only to be entered by the largest ships, after they had been lightened of their coals, stores, and a considerable part of their armaments. Now supposing them to be available during one-half of each tide, or in other words, for one-half of the days in the year, 9½ acres for 182½ days, compared with 48 acres for 365 days, was as 1,738 to 17,528, and these numbers might be taken as expressing approximately the accommodation of the basins of Portsmouth, as compared with those of Cherbourg.

"The inaccessibility of the basins and docks, at Portsmouth, during the greater part of every tide, was common to all those at the other dockyards, except Keyham, and the whole aggregate basin accommodation of all the dockyards, put together, (when the new basin at Keyham was completed,) would be 37½ acres.

"The space in Portsmouth Harbour, for large ships, was so limited, that even during the Crimean war, the duties were often at a standstill for want of room."[1]

In order to contend with the French, in the Channel, on equal terms, the accommodation of Portsmouth, for the repair and coaling of a fleet, must be rendered at least equal to that of Cherbourg. The amount of coaling and repair, required at present, was manifestly trifling to what would be necessary, in time of war, and in time of peace the coaling and repair could be divided amongst half a dozen arsenals; but in time of war, it would be madness to divide the fleet, for such a purpose, in the face of an enemy concentrated at Cherbourg. Portsmouth must therefore be rendered adequate to supplying single handed all the requirements of the Channel fleet.

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[1] *Vide* "Naval Administration, its Faults and Defaults."

There were not any valid grounds for presuming, that coast and harbour fortifications, might not be rendered as defensible against iron-plated vessels of war, as former coast defences had proved themselves against timber-built ships. During the late war, it was proved, by repeated experiments, both in England and in France, that wrought-iron plates 4½ inches thick, were proof against heavier shot than could ever be brought to bear against any fortress, not on the sea-coast, and such plates had five years ago been actually applied in practice and deemed a sufficient protection to floating batteries, expressly designed to batter down coast defences mounting 68-pounder guns, and these floating batteries were armed as heavily as the Redan. Why should not coast batteries and martello towers and the bastions of land fortresses, be constructed like these floating batteries, of shot-proof iron plates, properly framed together as a substitute for masonry? The end in view, that of affording a certain number of guns a really gun-proof cover, was identical in each case; that end had been attained afloat, by substituting iron for wood. It might therefore be attained ashore, by substituting iron for stone, with equal certainty, and with far greater facility and economy, than afloat; for the application of so heavy a defensive material to a floating and sea-going craft, was evidently a more complicated problem, than its application to a structure on land. Such iron bastions would not, necessarily, cost much more than those of the usual construction, their greater compactness being taken into account; the guns might be mounted as close together as the battery of a line-of-battle ship, and in tier above tier, so as to counterbalance the wider front of the enemy's fire. The parapet being only 4½ inches thick, each embrasure would present a range of fire of maximum width, in proportion to the space exposed; and that might be reduced to an orifice little larger than the muzzle of the gun, if breech-loading cannon, or moveable shot-proof sliding shutters, were employed; the muzzle being the only part of the gun exposed to the enemy's fire.

The heaviest hostile fire could produce but little sensible impression, either on guns so protected, or on the men who worked them; nor could such works be breached; and under such conditions the curtains connecting the bastions might be mere earthwork, and the cost of the whole system of enceinte thus be reduced below that of the usual modern system, over which it would possess the material advantage, of giving to the defence a positive superiority over the attack. And small machicolated wrought-iron martello towers, with sloping and impervious iron roofs, might be erected, to command points favourable for debarkation, which could not be reduced by any agency except famine, and which would do infinite damage to an enemy in landing.

The great strength and toughness of wrought iron, and the equality of its strength in all directions, the ease with which, in the largest masses, it could be moulded beneath the steam hammer to any required form, and the practicability of making a wrought-iron structure in a number of pieces, nearly as strong as if only in one piece, combined to render this material the best adapted to resist violent impact, like that of the fire of artillery.

The system introduced by Lieutenant Rodman of the United States Artillery, of casting iron guns hollow on a chilled core, which Mr. Conybeare had described in the discussion on the Construction of Artillery during the last Session,[1] had rendered it practicable to cast much larger guns than any previously in use, and thus to provide guns for coast defences, which were much more powerful and heavy than any iron-plated vessel could carry, and at the same time capable of crushing in the sides of the heaviest armour that could ever be carried afloat. A cannon weighing 35 tons had been stated to have been successfully cast, on this system, at the Fort Pitt Foundry, Pittsburg, under the superintendence of Lieutenant Rodman; it was 15 inches in the bore, 50 inches in external diameter, and 19 feet 5 inches long. It was evident that no vessel could be plated with iron sufficiently thick to withstand artillery of this class, which might be mounted in batteries composed of plate iron, heavier than any vessels could carry. It was therefore clear, that the increase in the weight of ordnance and the introduction of iron-plated batteries, still left to coast batteries a decided superiority over assailants afloat.

It had been said, that the increased range of modern rifled ordnance would enable an iron-plated frigate to bombard an arsenal from a distance, at which she would herself be safe; such distance exceeding moreover the extreme range of former guns. This conclusion however appeared to be ill-founded; for there was no case on record, of a heavy rifle-shell gun having exceeded in range that of the 13-inch mortar, or the Monk 56-lbs. that had been in use nearly twenty years. During the late experiments, at Southport, with Whitworth's 80-pounder gun, the greatest range obtained (at an elevation of 10°) was only 4,700 yards. Nor would the security of the assailants be practically greater than it was at present, because, according to Sir Howard Douglas, a mortar vessel engaged at long range in bombarding so large a target as an arsenal, was itself too small an object to be in any real danger of being hit, and consequently a bombardment from the sea could be effected at as long a range and with as little danger to the assailants, as at present.

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[1] *Vide* Minutes of Proceedings Inst. C. E., vol. xix., p. 387.

In the course of this discussion a complaint had been made, that notwithstanding the time and the money that had been expended on experiments, the country was still without any powerful guns, either for naval purposes, or for coast defence. There were obvious grounds for this complaint, for the French iron-plated frigates were already armed with rifle guns of the calibre of 50 lbs., but throwing an elongated percussion shell of 84-lbs. weight; while the English navy had not anything more effective than the old-fashioned 68-pounder guns.

The mechanical ingenuity, shown in the working out of the details of Sir W. Armstrong's gun, was beyond all praise, but with his principle of forcing the ball into the gun and of breech loading, it was now generally supposed to be inapplicable to heavy guns.

There were two great classes of projectiles for rifles and rifled ordnance,—1st, those made with projections to fit the grooves, like the Whitworth Jacob rifle and the French rifled ordnance, and — 2ndly, smooth leaden or lead-coated projectiles, which were driven into the grooves, by the force of the explosion, like the projectiles of Sir William Armstrong. In the latter case, the force (amounting to several tons) expended in forcing the ball into the grooves, was so much subtracted from the useful effect of the powder, and so much added to the stress on the fabric of the gun, and the increase of the resistance the ball had to overcome, necessarily increased the recoil; for when the whole force of the powder was utilised, in imparting a forward velocity to the ball, the velocity, so imparted, would be necessarily greater, than when a considerable portion of its whole force was absorbed in overcoming a resistance in the barrel, amounting to several tons; and every sportsman knew how considerably the increase of resistance in the barrel, due to its fouling, after repeated discharges, increased the recoil of his gun. Anything that increased the friction, increased also the recoil, and lessened the initial velocity of the shot. A portion of that power, which should be beneficially employed in expelling the shot, was uselessly expended in overcoming friction, causing at the same time more recoil. A good authority had said:—"The greatest efficiency of the explosion is destroyed if the shot be prevented, by unnecessary friction, from starting gradually on its course, with the very slightest force that first affects it; all great velocities are the termination of gradually accelerated motion."[1]

There were also two means of closing the breech of a breech-loading gun so as to prevent the escape of the exploding gases. The first was that of the capsule cartridges introduced by Le Faucheux, twenty years since, and now adopted, with slight variations, in the Whitworth gun, and in all the more recent forms of sporting breech-loading fowling pieces. The second was the movable breech plug, with mitred surfaces of soft copper, as adopted in the Armstrong gun. Of the two the Le Faucheux principle was the best; the moveable plug breech not being nearly so efficient in preventing the escape of the explosive gases, as the capsule cartridge. The soft copper surfaces of the breech plug and plug seat of the Armstrong gun were, moreover, peculiarly liable to be defaced, and were likely to require constant grinding up, to maintain them in a gas-proof condition.

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[1] *Vide* Stonehenge on the Gun and Sporting Rifle.

Sir WILLIAM ARMSTRONG said, that the present discussion on National Defences, afforded him an opportunity of continuing his former observations, upon the subject of the rifled artillery in use in Her Majesty's service.

When he last addressed the Institution upon that subject, he had one of his 12-pounder rifled guns before him, and he then explained, that it consisted of an aggregation of coiled iron cylinders. That mode of construction remained the same, and he most firmly believed it to be the best, for all sizes of rifled guns, and more especially for those of large calibre. He had, in some instances, to a certain extent, departed from it, but only under the pressure of great manufacturing difficulties, since happily overcome.

He had learned, by experience, to have great distrust in the uniform soundness of iron, forged in large masses. The flaws could not be seen, except when they extended to the surface, and they were almost sure to run longitudinally, which was the most unfavourable direction in which they could occur. By the coil plan, they would always lie in a direction transverse to the bore, where they had but little influence upon the strength of the gun. Still more did he distrust steel, forged in large masses, including that variety of it called homogeneous iron. Even in forgings of the moderate size required for breech screws and vent pieces, the greatest difficulty had been found, in obtaining steel of a satisfactory quality; and in experiments made with mantlets and armour plates, it had been found, that although steel possessed admirable powers of resistance, in the form of thin plates, yet in the thick form it was inferior to wrought iron. He, therefore, adhered, with the utmost confidence, to wrought iron, as the best material for the construction of rifled guns, and to the coil principle, as the best mode of applying that material.

The breech-loading apparatus, explained on the former occasion, remained the same, and was now exhibited in the small gun,—a

6-pounder,—upon the table. The only modification was in the vent piece, upon the back of which a projection had been formed, to fit into the hole through the screw, and to prevent the occasional blowing out of the vent piece, from neglect in not screwing up the breech.

The sights had been improved, and a number of small pins and screws, which were found liable to be shaken out, or to be broken by the concussion of firing, had been dispensed with; but in all essential particulars, the gun remained the same, and he was happy to say it had met with the general approval of the service.

The projectile for the 12-pounder also continued unaltered, except in some unimportant particulars which need not be explained. It would be recollected, that it consisted of a thin cast-iron case, built up internally with segments, like bricks in a wall, and that it was thinly coated with lead, on the outside of the case. This projectile was used indiscriminately as solid shot, shrapnell shell, and as common case, or canister, according to the mode of dealing with the fuze.

The leaden coating of this projectile had been subjected to severe criticism. It was said to be liable to be stripped off, and to inflict injury upon friendly troops, in advance of the gun. He would explain this matter fully, and it would be seen how much more had been made of the objection than it deserved, and how little the objectors understood the merits of the case. The frequency of the occurrence had been greatly exaggerated. The heaps of recovered projectiles denuded of their lead, which were to be seen at Woolwich and at Shoeburyness, had given rise to the belief, that the lead had in every instance been stripped off as the projectile left the gun, whereas the separation took place on the graze of the projectile and not on the firing of the gun, except on rare occasions. It was a well-ascertained fact, that the lead, when it separated on leaving the gun, generally struck the ground within a distance of 100 yards, and invariably within a distance of 200 yards. It must be obvious, that artillery would never be fired over the heads of troops at so short a distance, except in cases of extreme emergency, because in the event of shells bursting at the muzzle, as they must always be more, or less liable to do, the casualties would be much more serious, than could arise from the lead coming off. But whatever might be the weight of the objection, the rational inquiry was, whether it were of a radical, or of a remediable character. At all events, those who condemned the projectile, on that account, should be prepared to produce one equally efficient, and free from this liability. It was not sufficient to say that this, or that person's projectile might be so modified as to combine the good points of both plans. If it were practicable, let it be done, for in matters of invention the difference between saying and doing was as wide as possible.

The truth was, that any amount of adhesion might be given to the lead; but it was doubtful to what extent that adhesion could be increased without impairing the efficiency of the shell. The nature of the case would be understood, when attention was directed to the specimens of 12-pounder shells, then exhibited. The first was a shell having the lead put on with tin solder, in the ordinary way. It would be seen, that in this case the adhesion of the lead was so feeble, that when cut through, it could be peeled off with the fingers.

The second was a shell having the lead put on, without the application of any solder at all; the adhesion being obtained by means of undercut grooves, which held the lead with much more tenacity than the tin solder.

The third was a shell, in which the lead was put on with zinc solder,—a method he believed first practiced by Mr. Bashley Britten, in connection with his own projectiles, and afterwards proposed by Colonel Boxer for the projectiles of the Armstrong guns. In this last case, the adhesion of the lead was so perfect, that the junction was as strong as the material. It would therefore be asked, why not adopt the zinc solder and put an end to the question? The answer was, that by increasing the adhesion of the lead, the number of splinters, produced by the bursting of the shell, was diminished.

Samples of 12-pounder shells were exhibited, in the fragmentary state produced by bursting them in a chamber, where the pieces could be collected.

	Number of Large and Small Pieces into which the Shell burst.
First sample—the lead being attached in the ordinary way	310 pieces.
Second sample—the lead being secured by undercut grooves	292 „
Third sample—the lead being attached by zinc solder	243 „

The effect of this last system was to produce only about four-fifths of the number of pieces contained in the first sample. In the latter case also, every fragment of iron carried its piece of lead, so that nothing was added by the lead to the number of splinters.

Individually, he had no particular preference for any one of these methods; but the question was, whether it was advisable to sacrifice one-fifth of the number of fragments, for the sake of preventing the occasional separation of the lead, at the muzzle of the gun?

For solid shot, (which, however, were but little used with these guns,) there could be no objection to zinc solder; and in regard to shells, the undercut plan would probably prove the best; because it did not seriously diminish the number of fragments, and would afford an adhesion, independent of chemical action.

Various specimens of large projectiles were exhibited, and amongst others were the common and the segment shell for the 100-pounder gun. There was also a steel-headed shot for the same gun. The steel part, which formed the larger portion of the projectile, was a cylinder, carrying an external casing of cast iron, coated with lead. The steel bolt was flat-headed, as advocated by Mr. Whitworth, the object being to punch a hole in the plate; but it was probable, that no great damage would be inflicted upon iron-plated ships, except by using projectiles of such weight and magnitude, as would crush in the side of a ship, instead of merely punching holes in it. Experiments were in progress, at Shoeburyness, with lead-coated shells filled with molten iron, and no difficulty had been found, in preventing the lead covering from being melted off.

A description of the time and concussion fuzes had already been communicated to the Institution, on a former occasion,[1] and specimens of these were again exhibited. He had now to describe a fuze which he had lately perfected, and which had since been adopted for the sea-service shells, of rifled ordnance. As all attempts at secresy upon these matters had been wisely given up, as utterly impracticable in this country, he felt no scruple in describing this fuze, more especially as he knew, that specimens had been stolen from the factory at Elswick, under circumstances which could leave no doubt of their being intended for transmission to foreign countries. Not that he believed they would be readily adopted there, because professional prejudice, and the difficulty of engrafting novelties, upon systems already in existence, were much more effectual safeguards, than attempted secresy.

Before proceeding to describe this fuze, he would offer one, or two observations, on the difference of the conditions required in a percussion fuze, for sea service and for land service. In both forms it was necessary, that the fuze should be so constructed, as to resist explosion, under the greatest amount of violence to which it might chance to be exposed, in transport, or in handling; but, at the same time, the construction must be such, that the act of firing the shell from the gun should have the effect of putting the fuze, as it were, from half cock to full cock, and thus giving it a sensibility, which it did not previously possess. There was, however, this important difference in the two cases. In the land-service fuze the sensibility, thus acquired, could not be too great. The shell ought to explode, if it did but strike a man's hat; but in the sea-service fuze, the sensibility must be limited, because a considerable proportion of the shells would ricochet from the water, and if they were to explode from that concussion, the chance of their subsequently striking a ship would be lost.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xix., p. 409, *et seq.*

Another important object, in the sea-service fuze, was to attain the greatest possible rapidity of action, so that the explosion might take place either in the act of passing through the timber, or instantly on entering the ship. Sir Howard Douglas had objected to the use of percussion shells, upon the ground that they passed the fighting side of a ship before they exploded, and wasted their effects upon the opposite side, where the men were not engaged. Quickness was, therefore, a most important consideration; and when he stated, that the time which a shell occupied in passing through the side of a ship, was only about $\frac{1}{400}$th part of a second, and that in that minute interval of time, all the movements in the fuze must take place, that the flame from the detonator must travel into the shell, and that the combustion of the powder must be sufficiently effected, to burst the shell, it would be seen how necessary it was, to reduce the times for those processes, to the smallest possible limit.

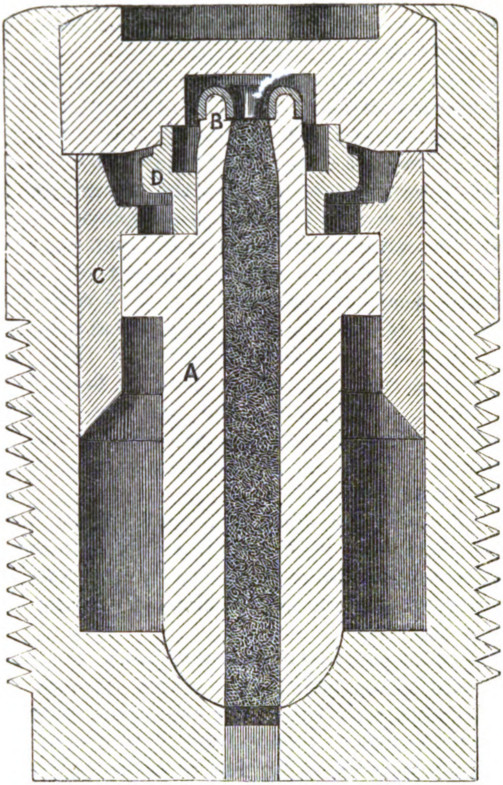
He then proceeded to describe the sea-service fuze, which he stated he had designed, with a view to the attainment of these objects, and which he had termed the 'pillar fuze.' Specimens of the fuze were exhibited, and sections of it were shown by the drawings upon the wall.

It consisted of an external case screwed to fit the shell, and containing a central pillar, which had a hole through it, filled with powder, and which was tipped at the upper extremity with a detonating composition. This extremity projected into a cavity in the cover, a clearance being left of about half a tenth of an inch, all round the detonator.

It would be seen, that if the pillar were to move forwards, or to one side, the detonator would explode, by striking, in the one case against the top, and in the other against the side of the cavity. It was, therefore, necessary to secure the pillar in its central position, in order to be perfectly safe in transport and in handling. This was effected by applying a leaden hoop, called the guard, which filled up the space around the pillar and prevented any lateral movement. The hoop also rested upon a collar in the pillar, by means of a flange, and abutted, at the upper end, against the cover, thus preventing any longitudinal movement. In fact, until the guard were dislodged, the pillar did not admit of any movement whatever. This, then, would be the condition of the fuze, before the gun was fired; and in that condition, (as represented in

Fig. 3.) it was capable of resisting any amount of accidental violence, to which it could be exposed. But when it was fired from the gun, the motion communicated to the shell was so sudden and rapid, that the *vis inertiæ* of the guard caused the flange to be stripped off, and the guard to be lodged at the bottom of the fuze, as represented in Fig. 4; (page 477). In this condition the pillar would have lost the support of the guard, but it would still derive support from a little leaden cup, which was called the regulator, because by increasing, or diminishing the thickness of this cup, the sensibility of the fuze was regulated to the required degree. In determining the strength of this cup, the object was to make it of such a thickness, that the pillar should be retained in its position, when the shell struck upon water, but not when it met with a greater resist-

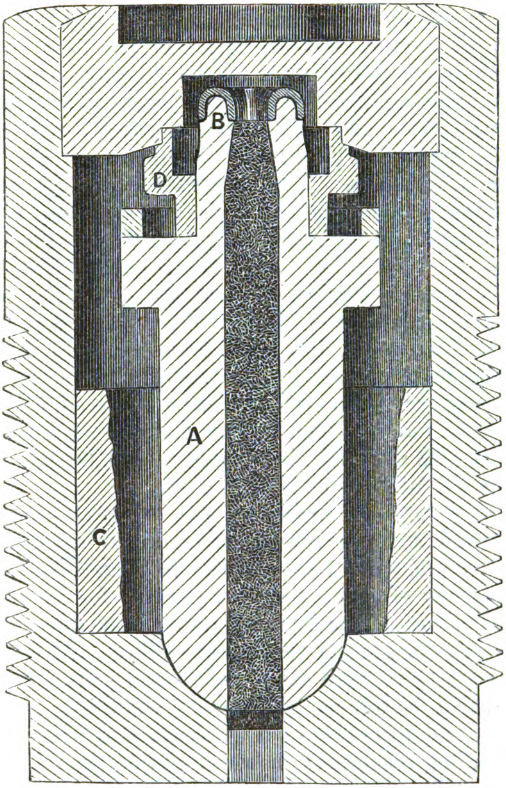
Fig. 3.



Pillar Fuze—Condition before firing the Gun.
A, the Pillar. C, the Guard.
B, the Detonator. D, the Regulator.

ance. Supposing the shell to strike its object,—a ship for instance, —point foremost; in that case the velocity of the shell was checked,

Fig. 4.



Pillar Fuze—Condition during Flight.

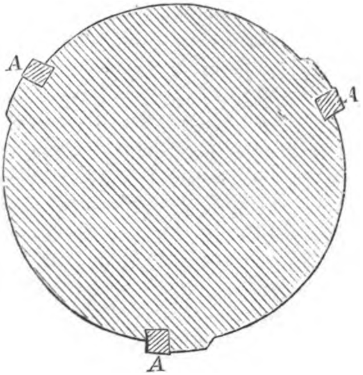
and the momentum of the pillar would crush up the cup and bring the detonator into contact with the top. Again, supposing that the shell had been fired at a high angle, in which case it would fall upon its side; or that in consequence of grazing upon the water, it should strike a ship sideways, the momentum of the pillar would take effect in a lateral direction, and the lip of the cup which projected into a recess in the cover, would be cut off, thereby bringing the detonator in contact with the side. The action obtained, by this arrangement, was extremely rapid, because the amount of movement in the pillar was very small; also because the detonator was in immediate contact with the priming powder in the pillar, and a strong jet of flame was instantly shot from the fuze into the shell. So rapid was the action, that in firing a 100-pounder shell, against a butt 18 inches in thickness, the shells were burst in the act of passing through the timber, and the shattering effects produced were most destructive.

The only point, in this description, which might not be quite intelligible to all present, was the nature of the force by which the flange of the guard was stripped off, on the firing of the gun. A few words of explanation would, however, make that clear. Taking, for instance, a 100-lbs. shell, fired from a gun of 7 inches bore, and assuming the maximum pressure of the gas, upon the base of the shell, to be 1,000 tons. This pressure would be equally distributed amongst all the particles of the projectile, so that each grain-weight would, at the instant of greatest pressure, have a force applied to it of about 3 lbs. Now the guard of the fuze, which weighed 300 grains, formed part of the projectile, and would, therefore, have a pressure of about 900 lbs. applied to it, urging it to move. But that would have to be transmitted to it, through the medium of the flange, which rested on the collar of the pillar, and which not being strong enough to bear a strain of 300 lbs. would break under the force applied. The guard, therefore, would not move forward with the shell, but would be left behind, until it was caught up by the bottom of the fuze case.

Proceeding to another branch of the subject,—muzzle-loading guns,—he stated, that his conviction remained unshaken, not only that breech-loading guns were superior to muzzle-loading guns, in the great majority of cases,—more especially for naval use,—but that the application of the breech-loading principle was mechanically practicable for guns of very large calibre. At the same time he would admit, there were cases, as in open forts, where the guns would necessarily be left in an exposed condition, and could not have the care and attention of a garrison, and where any species of breech-loading machinery, however simple, would be objectionable. In all such cases, muzzle-loading guns would be preferable, and it was therefore probable that they would always be, to some extent, required.

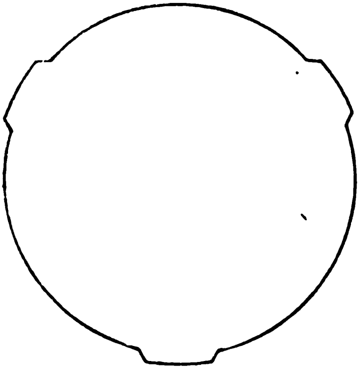
The first consideration in a muzzle-loading gun, was facility of loading, and to accomplish that, it was necessary, that the gauge of the shot should be sufficiently low, to prevent it from sticking, in going down the bore. But, on the other hand, it was necessary, in order to insure accuracy of fire, that the shot should not admit of any lateral movement, as it issued from the gun; the question, therefore, was how to make the projectile go in easily and come out tight. He would explain how this was effected in the gun which he had called the 'shunt gun,' and would first describe the projectile. There were two of these projectiles exhibited. They were adapted for a 7-inch bore, and one of them had been actually fired. The projectile was shown in section in Fig. 5. It was fitted with three bars of zinc, which ran the whole length of the cylindrical part of the shot. These bars were very narrow, being only $\frac{4}{10}$ths of an inch in width, and were backed up behind by cast iron, so that the entire rib consisted partly of zinc, and partly of cast iron, the cast iron being a little below the level of the zinc.

Fig. 5.



Section of Shot.
A, A, A, Zinc Ribs.

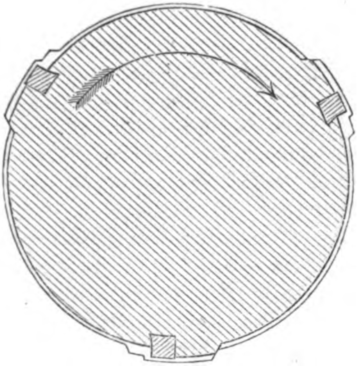
Fig. 6.



Section through the body of the Gun.

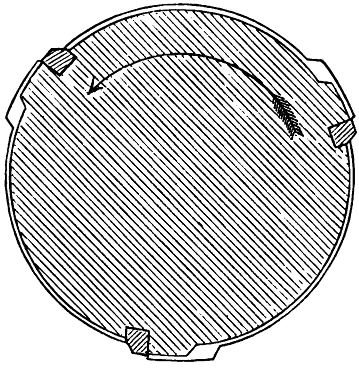
In describing the gun he referred to Fig. 6, which showed a section through the body of the gun. Figs. 7 and 8, (page 480,) showed sections at the muzzle, and exhibited the shot in the one case, as it entered, and in the other case, as it came out. It would be observed, that the grooves at the muzzle were slightly wider than they were lower down, and that they were stepped, or had two levels, the lower one corresponding in width with the entire rib, and the upper one being somewhat narrower than the zinc bar. But the projectile would only enter by the low level, or deeper portions of the grooves, because the gauge, measured over the zinc, was a little in excess of the high level, or shallower portions.

Fig. 7.



Section at the Muzzle—Shot going in.

Fig. 8.



Section at the Muzzle— Shot coming out.

Fig. 9, (page 481,) was a development of one of these grooves. It would be seen, that the high level part of the groove continued parallel, for 8 inches from the muzzle, at which part an incline commenced, and ran off to nothing, at 14 inches lower down. Supposing the spiral direction of this groove to be such, that the rib of the shot in going down, would hug the right side of the groove, as viewed from the muzzle, then in coming out, it would hug the left side, because the rotation would be in the contrary direction. By referring to the drawing, it would be seen, that as the shot went down, it would meet with a curve which would deflect the course of the rib, or shunt it to the side upon which the high level was situated. But at this point the high level had become extinct, so that the shot would pursue an easy-fitting course all the way down. But in coming out, it would not be affected by the curve, or shunt, because it would then be hugging the opposite side. It would, therefore, take the high level, or tight-fitting course, when it reached the incline, and would issue by that course, as represented in Fig. 8. In that figure, it would be seen, that although the cast-iron part of the projectile was clear of the bore all round, yet that the zinc ribs were in close contact with the high level portions of the grooves. The zinc bars would, in fact, be undergoing compression, and no vibration could therefore exist, at the instant of the projectile quitting the gun; but the compressed material being soft, no strain would be put upon the gun, to affect its stability.

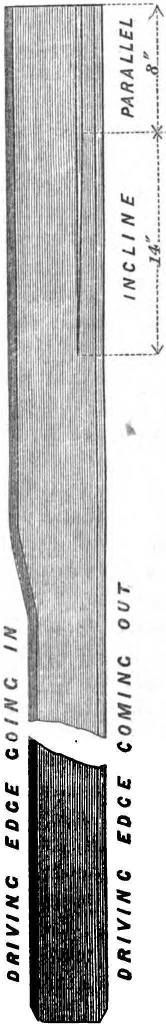


Fig. 9.

Development of Groove in the Shunt Gun.

The principle of using soft metal ribs, possessed also the great advantage of self-adaptation to the form of the groove; each rib taking precisely its proper share of the pressure, without involving accurate workmanship. It would be seen by Fig. 5, (page 479,) that the zinc bars were put in square, the bevel to fit the groove being acquired by the pressure producing rotation; (Fig. 8). All risk of jamming, in case of obstruction, and all liability to abrasion in the grooves, were obviated, by the use of soft metal ribs, while the projectile might be a mere casting, without any tool-work upon it. A projectile having these properties, was preferable to one which required to be tool-fitted, and still more so to a projectile merely cast to the form of the bore, and made wholly of hard material.

A 120-pounder gun, upon the shunt principle, was then under trial at Shoeburyness, and nothing could be more satisfactory than the results, so far as the experiments had proceeded.

The success of this projectile, its simplicity, and its economy of manufacture had naturally suggested its application to breech-loading, as well as to muzzle-loading guns; but the advantage which the leaded shell possessed, with regard to the number of fragments produced upon explosion, and also its peculiar adaptation to the segmental principle, admitting as it did, of a much thinner shell being used, than would otherwise be practicable, had induced a preference for it, so far as the smaller descriptions of projectiles were concerned. But for large projectiles, which would be chiefly used for battering purposes, or for producing great explosive effect, it was probable, that the soft-rib principle might be adopted, at a saving of cost, and without diminution of efficiency.

In order to avoid the necessity of lifting the vent piece, which in large guns became inconveniently heavy, he had long been endeavouring to make it slide out sideways. The first large gun he had made, was constructed in this manner; but the objections which had presented themselves to that arrangement, were first, that the escape of gas at the breech, which in the vertical arrangement was of no importance, became a serious inconvenience, when it took place from the side: and secondly, that in the event of the gun being fired, before the vent piece was screwed up, the mischief would be much more serious, than if the opening were at the top of the gun. He did not, at the time, see how these difficulties could be surmounted, but he had at length arrived at a construction, by which the object could be accomplished, without the liabilities described.

A full-sized model of the breech of a 100-pounder gun, constructed upon this principle, was exhibited: but before describing it, he would observe, that the problem to be solved was; first, to construct a breech-closing apparatus, which would work from the side, so as to obviate the necessity of lifting the parts: secondly, to entirely prevent the escape of gas: and thirdly, so to arrange the apparatus, that the gun could not be fired, until the process of closing the breech had been perfected. The first step towards the attainment of this object, consisted in the application of a thin iron cup, to act, upon the principle of a pump leather, in preventing the escape of gas from the breech. This had been applied to the ordinary 100-pounder guns, and was found to answer perfectly. The Prussians originally adopted a cardboard cup, for the same purpose, and for small charges, such as they used, that substance answered very well, but it would not bear the heavier charges employed in this country. Thin sheet-iron, however, answered perfectly for the cups, and they could be made at a small cost.

He then proceeded to describe the model. In the ordinary construction of the Armstrong gun, the slot, or chamber, which received the vent piece, was cut through the gun, in a vertical direction, whereas in the model, it passed through horizontally. This slot, or chamber, contained a stopper, corresponding in its function to the vent piece; but in this case called a stopper, because the vent was in the gun and not in the stopper. It also contained a sliding block, slightly wedge-shaped at the back, and which performed the part of the screw, in the other arrangement. Where the prevention of the escape of gas depended upon the mere pressure of well-fitting surfaces, the application of a screw was requisite, to render the contact of those surfaces sufficiently close; but where the prevention of escape was effected by a cup, it was only necessary to give support to the stopper, and hence the screw was dispensed with. The sliding block was fitted with a running handle, which acted as a hammer, in overcoming the friction of the block against the stopper. By first using the handle as a hammer, and then applying a gentle pressure, the block was thrust back against a stop, which prevented its going too far. The stopper was then drawn forward, by which means the breech was opened, and the shot and the charge of powder could then be inserted. The iron cup was next applied to the projecting face of the stopper, and by means of a button upon the face the cup was rendered a fixture, by giving it a portion of a turn. The next movement was to slide the stopper, with the cup affixed, into the chamber, as far as it would go, and by then changing the direction of the hand, and using the handle of the stopper as a lever, the cup was thrust into the bore, into which the face of the stopper entered about half an inch. It then only remained to draw up the block, and the process of closing the breech was completed.

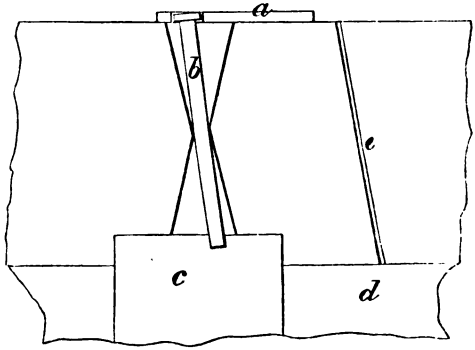
It would be observed, that the stopper, in coming out, was guided into a convenient position for affixing the cup, by means of two grooves, one on either side of the chamber, and that in going in, these grooves prevented any devious, or vibratory movements in the stopper, which would have the effect of bringing the cup in contact with any part of the gun, and thereby bruising its edge. But the grooves were also of such a form, that when the stopper had reached a point opposite the bore, then, and not till then, it became susceptible of the movement necessary for entering the cup. It would also be perceived, that the stopper, in coming out, was arrested at the proper place, so that it could not tumble out. But although it could not come out accidentally, it could be easily taken out designedly, by guiding it into a sort of siding, running out of the groove.

The apparatus for preventing the gun from being fired, before the breech was properly closed, was then described.

On the top of the gun there was a little slide, which worked to and fro, over the vent hole, and which participated in the motion of the block, so as to cover the vent hole, when the block was thrust back, and to uncover it, when the block returned to the position at which the gun might be fired with safety.

The apparatus by which this was effected was very simple. It merely consisted of a little slide and of a strong pin, communicating with the block, through a hole, which was contracted in the middle, and expanded above and below, as shown in Fig. 10. This form of hole allowed the pin to vibrate on its centre. The lower extremity of the pin projected into a groove in the block, which groove had a curve upon it, to give the required movement through the gun to the slide. The slide was covered by a hood, shown in the model, but for the sake of distinctness not indicated in Fig 10.

Fig. 10.



a, the Slide; *b*, the Pin; *c*, the Chamber containing the Block; *d*, the Bore; *e*, the Vent.

A 100-pounder gun, upon this principle, was now completed, and would be tried almost immediately. He had the greatest confidence in its success, as the details had been worked out with great skill and care by his able friend Mr. George Rendel, the managing partner of the Gun Department of the Elswick Ordnance Works. The gun was rifled upon the shunt principle, and would admit of being loaded from the muzzle, as well as at the breech, if that were of any importance. He would add, that this form of gun was not a new idea. He had been working at it, more, or less, for the last two years, and he believed he had acted discreetly, in not attempting to bring it forward, until it had been fully matured. Even yet it must be carefully tried, before it could be adopted, because, although he believed it to be an important step in advance, as regarded guns of large dimensions, yet the large guns already made upon his original plan, had given very satisfactory results; and the new plan must, therefore, not be taken as the future type, until its superiority had been thoroughly established.

So far as the shunt principle of rifling was concerned, he brought it forward in the early part of the year 1859, and recorded it in a provisional specification for a patent; and he first applied the side movement of the breech arrangement, though in a less perfect form, to a large gun made about the same period.

He still considered the leaded shell and the old arrangement of screw and vent piece the best, except for large guns: and the innovation proposed, must not, therefore, be regarded as any abandonment of his former principles. But even if it were, he was pledged to nothing, except to do his best for the public service, and to make improvements as rapidly as he could.

He would next briefly advert to a subject, upon which he wished he could have been silent. The President, upon a former evening, had animadverted, somewhat severely, upon the officials of the War Office, for throwing obstructions in the way of a trial between the Whitworth and the Armstrong guns. Situated as he was, being so closely connected with the War Department, and personally so much interested in this question, it was impossible for him not to feel in some degree involved in this condemnation. He was reluctant to make any observation which could provoke controversy, or discord, between Mr. Whitworth and himself; because, considering the circumstances of rivalry and antagonism which had existed between them, in this matter, they had always remained good friends. But it was necessary to exonerate himself, by declaring that he at once agreed, not only to the original programme submitted to him, but also to a second one, framed, as he understood, to meet the wishes of Mr. Whitworth. It was so usual, in all such cases, to attribute blame to the Ordnance Select Committee, that he did not think any indefinite imputations of partiality, or prejudice, should be allowed to influence the Institution. At all events, so far as he was concerned, he was quite willing that the Institution should see the programmes which had been agreed to by him, and which had not been accepted by Mr. Whitworth.

Mr. T. E. HARRISON begged to ask whether, as had been stated in one of the scientific magazines of the day, Sir William Armstrong had patented his latest improvements in breech-loading, for his own emolument? He had known Sir William for so many years, and was so satisfied that such a feeling was contrary to every principle, which had actuated him throughout the whole of his course, that he had no hesitation in putting the question, with the fullest confidence that a contradiction would be given to the statement.

Sir WILLIAM ARMSTRONG replied, that he had not the slightest difficulty in contradicting it. It had been his practice, in reference to nearly all his improvements relating to gunnery, to take the first step in a patent, by lodging a provisional specification, for the purpose of recording the invention, and for preventing other persons from taking out a patent for the same thing. But it would be quite abortive on his part, to take out a complete patent for this, or for any other invention relating to guns, since his agreement with the Government authorities was, that while he held his present office, they should be entitled both to his services and to his inventions. He might add, that it was perfectly untrue, that he had received £20,000 from the Government. His salary was his only remuneration; and although the Government was pledged to a continuance of his engagement, for a period of which five years remained to expire, he held them at perfect liberty to cancel the arrangement whenever they might think proper to do so.

Mr. BIDDER,—President,—referring to the previously-mentioned experiments, inquired what was the initial velocity of the shot, under the ordinary charge of one-sixth of the weight of the projectile?

Sir WILLIAM ARMSTRONG replied, that with a charge of powder one-eighth of the weight of the projectile, the initial velocity was about 1,180 feet per second; with a charge of one-seventh of the weight, it rose considerably above 1,200 feet. He had stated, on a former occasion, with regard to the powder chamber, that unless a maximum charge were used, there was a vacancy in the chamber, and that he had not observed any material diminution of velocity, as due to that vacancy. More accurate experiments had since shown, that there was a very appreciable diminution of velocity, and that beyond a certain limit it became considerable. But, on the other hand, there was this advantage in having a chamber, that in putting in the projectile, it stopped at a definite place. In loading from the breech, there was a risk, when no stop was provided, of the shot running forward in the bore, to a point considerably in advance of the charge. This was especially the case when the gun was fired with depression; and whenever that happened, there would be danger of bursting the gun. The cause of this was curious. The powder constituting the charge, was instantly converted, on ignition, into a weight of gaseous and liquid matter, corresponding with the weight of the charge. This weight of gas and liquid matter rushed forward with immense velocity, through the unoccupied space in front, until it reached the projectile, when the natural pressure of the gas became enormously augmented, by the momentum previously acquired by the particles, and there expended upon the base of the projectile, and on the adjacent part of the bore. But there was no such danger, if the cartridge were sufficiently elongated to reach to the projectile, even if there were vacant space around it.

It had not been ascertained, whether the velocity mentioned applied to the 100-pounder gun.

In reply to further questions put by the President, Sir W. Armstrong explained, that observations had been taken as to the time and space, so as to fix the law of retardation in the projectile. Experiments were in progress, at the present time, but they had not been reduced to a law. His own observations, as to time of flight, gave him a tolerable idea of the diminution of velocity; but he had not got the figures at present, so as to allow them to be used for scientific purposes. The experiments were still in progress, under the Ordnance Select Committee, and therefore it would be premature to give figures which could only be approximate.

Mr. W. CLAY said, the over-running of the shot was prevented by a collar upon the ramrod, which would only thus drive the shot to a certain length up the bore.

Sir WILLIAM ARMSTRONG replied, that this would not have the effect, if the shot were sent in with a run.

Colonel SIMMONS, R.E., would endeavour, in as succinct a manner as possible, to explain his views to the Meeting.

In the Paper which had been read, and in the discussion which had arisen out of it, one question, which had been brought prominently forward, was that of the sufficiency of the fleet alone, unaided by land defences, to secure the shores from insult. With reference to this question there was one point bearing on it, of the utmost importance, which had not been noticed during the discussion. He alluded to the law of conscription, which prevailed in France and in other continental countries,—that curse left as a legacy to Europe, by the French revolution, by which nations were enrolled, drilled, and armed against each other. By this conscription, the whole seafaring population of France might be said to belong to the Imperial navy; for although, as Captain Moorsom had stated, France might have only 35,000 seamen afloat, while England had 50,000 seamen and 30,000 marines; and although France had a much smaller seafaring population, from which to recruit her navy, than England possessed, yet by this law of conscription, all the French seafaring population had been trained for service, on board ships of war, had been taught how to handle guns, and were registered and ready for service, at the shortest notice, at least such of them as were within call. It was also well known, that the proportion of French seamen employed in the narrow seas near home, was greater, and therefore they were more easily got at, than British sailors, who in greater proportions were absent on distant voyages; whereas England, with all her seafaring population, had no large reserve of men, trained to serve on board ships of war, with which suddenly to increase her navy.

Therefore, to whatever extent, within certain limits, the ships and material of war possessed by other countries where the law of conscription was in force, were ready in their harbours and docks, to that extent must England always remember, that almost immediately after a declaration of war, the enemy's fleet would be ready for sea.

The actual fleet, in commission, was not any criterion of the power of France; but the true criterion was the number of ships and the quantity of material she had in readiness for commission.

For this reason, the outbreak of a war would always find England, comparatively, insufficiently prepared. It was impossible for Great Britain to keep a body of men in pay, in her navy, approaching in numbers to the whole seafaring population of France; therefore, for this cause, as well as others, which had been stated by previous speakers, the fleet of Great Britain might be found insufficient, alone, to protect her shores.

The great advantage, which any supposed continental enemy had over England, was derived, not only from this immense organisation, but also from the secresy with which, under the existing forms of government, preparations could be made, for bringing the forces into action.

It was not necessary to look far back, for an example of this. In 1859, this country was assured, contrary to the suspicions which had been awakened, that war was not intended; that assurance was re-echoed by those whose duty it was to be thoroughly informed of all that was going on in France; but within six weeks, the French army was actually in contact with the Austrian army, in a foreign country. What had been done once, might occur again; it might, in fact, be in progress at the present time, unknown to any one here.

Still this immense organisation ought not to alarm the nation, assuming that proper measures were taken, to secure a certain amount of time, to complete the necessary preparations. The British force broke down in the Crimea, in 1854; but happily sufficient time was allowed, before the end of the war, so that in 1856 Great Britain had regained her position, and her army was superior, both numerically and physically, to that of her allies; and so it would always be with the navy and the army, and invasion would become impossible, if sufficient time was allowed, (for which a very few weeks would suffice,) to get the national resources into working order.

This fact was as well known to other nations, as it was understood here. Foreign officers of distinction had observed upon it, in no unfriendly spirit, and hence they urged the necessity for an organisation, somewhat similar to the conscription. Although fully alive to the risk, Englishmen would hesitate to exchange it for that scourge, the conscription, or in fact for any system of forced service; but at the same time, it would be well to be assured, that such preparations had been made, as would, during the time of organisation, secure the country from any severe blow, by sea, or land. Absolute security, upon every point of the extended sea coast, must be regarded as an impossibility. Those buccaneering expeditions, recommended as a system of warfare against this country, by a distinguished naval officer,—a prince of France,—could never be entirely prevented; but those expeditions, however successful, could never affect Great Britain vitally, and must cease, whenever a force had been collected, sufficient to sweep the Channel.

By a "severe blow" was meant, the destruction of any important arsenal, or centre of trade, or an invasion on a large scale. And here, he submitted, that a great mistake had been made, in the appointment of the Defence Commission. The question referred to that Commission, and concerning which that Blue Book treated which the President referred to, at the commencement of the discussion, was not that of the national defences, but was limited to the consideration of the "state, condition, and sufficiency, of existing fortifications."

Commissions and Committees had been appointed, to consider various parts of the defences; but up to the present time Colonel Simmons was not aware, that any had ever been appointed to consider the national defences as a whole.

As a consequence, with a Government that changed every two, or three years, the country had no security, that the proper steps were taken,—that one Government followed in the same views as another,—that what one Government had commenced, another would finish,—and hence that feeling of constant uneasiness and those alternate fits of wasteful expenditure and of paring economy, which not only drained the purse of the country, but were fatal to efficiency, and which was the reason, why a body of Civil Engineers were so usefully discussing this great question.

The consideration of the means, by which the nation was, so to secure itself, as to gain time for the development of its warlike resources, was the main question. Here the sea and the land defences of the dockyards were of the greatest value. Any defence to be good, must be an active, and not a passive defence. To enable the fleet to keep the seas, in presence of a superior force, it must have some secure port of refuge; and whenever the fleet was of sufficient strength, to be absent, at a distance from its bases of operations, those bases must be well secured.

These appeared to be the only places, on the coasts, where fortifications on a large scale were necessary, and they were very limited in number. In fact it might be doubted, whether it was really necessary to fortify, in this way, by sea and land, any other base than Portsmouth. The ground round that arsenal was peculiarly favourable for defence. Portsmouth, including its roadsteads, within the Isle of Wight, was one of the largest ports in the world. It also occupied a most important strategical position, with reference to both the maritime and the land defences, being close to any possible naval, or land line of operations, which an enemy could take, in any possible invasion, or attempt on the Metropolis. No fleet, with an expedition requiring to be disembarked, could be sent against any point of the southern coast, whether to the east, or to the west of Portsmouth, without having assured the mastery of the Channel by blockading that port.

This operation, from the peculiarity of the double outlet by the Needles and Spithead, would entail the employment of a far superior force to that which might be blockaded. Therefore the mere fact of a fleet at Portsmouth, in case it could not keep the seas, was a great point gained.

If Portsmouth were fortified, as a "focus of refuge, or action," as a previous speaker had called the fortified dockyards, and were rendered secure against all attack by sea, or land, it might be doubted, whether any other place on the coast of England required the same precaution, and whether such defences, on other points, would not be positively injurious. If such fortifications were too multiplied, they would undoubtedly be so. They would encourage the dispersion of the fleet, instead of its concentration; and in war, as in mechanics, a concentration of power was the only way to secure great results. A stronger fleet, if dispersed, might be prevented from assembling, and be beaten in detail by a weaker force.

These fortified ports, moreover, would absorb the whole of the land army, and would leave the country no available means, by which to make an active defence on shore. If fortified and not fully garrisoned, they would be sources of uneasiness and elements of weakness, as they might be seized and then become really dangerous, as bases of land operations for the enemy. Therefore the number of existing fortresses, at any one time, must depend on the means available on shore, for their defence.

It was not meant, that roadsteads should not be protected by batteries, near which stray ships, or even small fleets, might find secure places of refuge, and which might be capable also of opposing a resistance to any small force, sent on shore to attack them. On the contrary, these were highly useful adjuncts to the general defensive system. Such works requiring few men to hold them, and the defence of which might be left in a great measure to local forces, were very different from huge fortresses, or rather entrenched camps, requiring at the least 8,000 or 10,000 men, and, in some cases, 15,000 or 20,000 men to hold them. Take for example Alderney, which had been referred to by the President. A good battery, to protect a stray ship, or two, might be advisable. It was not asserted, that it would be so, but it was difficult to perceive the use of works, which would abstract a force of 2,000 or 3,000 men, from the means of active defence in England. On the contrary, those works, looking at them from a strategical point of view, appeared to be an absolute misfortune. The troops required for their defence, would be about as useful, but not quite so, as the garrison of Kinburn was, in the defence of Sebastopol. They might make a gallant defence, but they had no connection, with the defence of England. If the fleet had the mastery of the channel, that island was not wanted, and if not, England dare not use it.

Another instance was Dover, which, if fortified and in the possession of the French, would be what Calais was to the English, in the olden times; a good *tête de pont.* Fortified by land as it was, and requiring, according to the Duke of Wellington, 10,000 men for its defence, it was an element of weakness. The town itself was not secured, by its fortifications, against bombardment, and those fortifications would abstract 10,000 men from the active defence of the kingdom. All that had been gained by these elaborate works at Dover, which had been fifty years in course of construction, would have been equally well gained by a good battery, or two, well protected at their gorges, in such a way, that they would not yield to a *coup de main*, but would prevent an enemy from using the roadstead, and would require him to disembark guns and to place them in position, to reduce them, and thus time would be gained for the active defence of the country to come into operation. By active defence was meant, a good powerful army, concentrated in some central position, and capable of immediate and rapid movement to any point, upon which a decided attack might be made.

The same observations applied to the defences of the Medway and of the Thames also, where distant from London. It was difficult to conceive the necessity, or the advisability of including a huge camp, of many square miles in extent, within the lines of Chatham and Sheerness. Chatham was a long way up a river, where it could be easily secured from naval attack; and where it could only be attacked by land, by an invading army, on the largest scale, which, with London before it, would never condescend to waste its time upon a comparatively insignificant dockyard. Whilst the 10,000 or 15,000 men required for its defence, could only be provided, at the expense of the active defence of the country at large.

By all means let good and efficient batteries, well protected at their gorges, be established along the shores of the Thames, and at the entrance of the Medway, to prevent an enemy's fleet from repeating the insult once offered to England, by the Dutch; but this was very different from shutting up a small army and frittering it away, by dividing and subdividing it, in garrisons, where it would be deprived of the power of concentration and of taking part in the real defence of the country. These same arguments would probably apply to other places, and even to Plymouth, to Milford, and to Cork.

In making these observations, no reflections were attempted to be cast upon the Report of the Defence Commissioners. They, as a body of Engineers,—naval, military, and civil,—had a special question referred to them. They were to report on the best means of fortifying certain "existing" fortresses, which were named to them. They were not instructed to report on the utility of those fortresses,—that was no part of the reference made to them, —as a body of Engineers they had a professional duty to perform. It was as if a company called on a Civil Engineer to make a railway, between any two given points; he might be of opinion, that the railway would not be of any great utility, but that was a commercial, not an engineering question, and therefore he would proceed with the construction; delighted no doubt at getting a field for the display of his engineering talents. The land forces of Great Britain, if ever required for the defence of the country, could not afford absolute security to the coasts, they could not be everywhere, at one and the same time, to prevent insult, but comparatively small though they were, they could secure the country against any severe blow, and against invasion on a large scale, if the true principles of war were applied in the disposal of them. The great art of war was to be stronger, than the enemy, at the point of attack. This was only to be done by concentration. Now the great object of any invasion, if ever it occurred, would be the Metropolis. Therefore the forces ought to be so disposed, that they might be concentrated in the greatest possible numbers, to cover the Metropolis. In such a position, they would be equally well, if not better placed for the protection of distant points, than if they were dispersed throughout the country, in small detachments. The radiation of the railways from the Metropolis, and the great concentration of means of transport, always available near it, gave greater facility for the transmission of a force, to any threatened point, than any cross line of railway could possibly give.

Now in order to defend the Metropolis, secure positions, or bases of operation should be prepared, in which, in case of necessity, it would be possible to assemble, brigade and equip the forces, consisting of Regulars, Militia, and Volunteers, which, until they had gone through these processes, were only an unmanageable mob. These bases, should be carefully and permanently intrenched camps, say 15 or 20 miles from London, and should contain the material necessary for the equipment of the army. It might, probably, be advisable to have two such positions, one on each side of the Thames, to provide against the possible contingency of an attack from either side. Such camps would give every scope and freedom to the action of the army.

The whole, or part of the army, could be risked in contact with an enemy, however numerous, to check his advance, and time thus be gained, for the concentration of all the means of defence, in absolute security. The army, if obliged to recoil, would be in a secure position, and in such force, that no enemy would risk his communications, by passing it, to enter a metropolis full of exasperated inhabitants. With two such positions, one on the north and the other on the south side of the Thames, a hostile occupation of the Metropolis, might be considered impossible.

No other system, short of maintaining a huge army and navy, far beyond that which at present existed, could afford security to the Metropolis, which, a very distinguished general officer of a foreign army, in speaking of the defence of England, described as being "very inconveniently near to the sea;" and it was evident, that the construction of two such camps, as had been described, was not only feasible, but need not be excessively costly.

The situation of Woolwich, and the extent of the works, which the Commissioners declared to be necessary, for its complete protection;—viz., 8½ miles of works on the south side, and between 8 and 9 miles on the north side of the Thames,—must convince every one that the locating of the great military manufacturing establishments, in such a place, was a misfortune deeply to be regretted. It was to be hoped, therefore, that those establishments would not be enlarged, but that, whatever further development those factories might receive, would be by building in some secure and central position in the midland counties, such as on Cannock Chase, where they might serve as a second base, and as a rallying point, in the active defence of the country.

In what he had said, Colonel Simmons had endeavoured to show:—

1st. That what was required by England, was time to prepare and to develop her warlike resources, so as to be able to oppose the great means always in readiness to be brought against her.

2nd. That the fleet was insufficient alone, for the defence of England.

3rd. That the question of the National Defences, had never been considered, as a whole, by any special Commission, or Committee.

4th. That if so considered, upon sound strategical principles, the number of the fortresses, and possibly of the dockyards, should be diminished. If so, the disposal of some of the latter, might go far towards defraying the expense of works of defence for the others.

5th. The diminution of the number of points necessary to be defended, would add greatly to the power of the small disposable army, and render it available as an active army, either for offence, or defence.

6th. The necessity of preparing secure bases of operation for that army.

A Commission on the National Defences of Belgium, some years ago, recommended that her frontier fortresses should be razed, and her energies be steadily devoted to the defences of Antwerp. A similar commission in this country would most probably, he believed, lead to somewhat similar results.

For giving these opinions, Colonel Simmons might, perhaps, be accused of speaking against the application of science and art, by the particular branch of the profession to which he belonged, but of this he felt confident, that he spoke in the interest of that which all in the Institution had warmly and truly at heart;—the inviolability of an Englishman's island home.

Colonel Sale,—through the Secretary,—said he was glad to have an opportunity of expressing his cordial concurrence with the opinions of the Author of the Paper, as well as with the opinions of Colonels Lysons and Simmons.

There could be no doubt of the main defence of the country depending on the quality of the navy; and the Author had exhibited great judgment, in directing his observations to ships as the prominent feature of the Paper. The vessels best adapted for opposing an invasion, by attacking transports and the convoying fleet, would be such as combined speed with a heavy armament. In future, iron and steel must enter very largely into the construction of vessels of war; and all the Reports were conclusive, in favour of the use of those metals.

From the nature of his past employment in the public service, it might be assumed, that Colonel Sale's predilections would have been in favour of land defences; but mature reflection had convinced him, that the safety of the country must mainly depend on the strength of the fleet. No effort should be spared, in putting it in the most efficient condition, both with regard to men and materials.

Nevertheless such a contingency might happen, that the fleet would not be able to prevent the landing of an enemy; and in such a case it would be necessary to be provided with means of defence on land. The mode of provision admitted of great difference of opinion, and it was to be regretted, that the question had been narrowed to the immediate defence of the dockyards and arsenals, without sufficiently considering the chief end and object of an invading enemy. It required but little imagination to conceive the enthusiasm with which the prospect of the plunder, or the ransom of the rich Metropolis, would inspire the minds of an invading force. If a landing were effected, a push would be made for the Metropolis, to the neglect of the fortresses of Dover, or Portsmouth, except, perhaps, by detaching a few thousand men to hold them in check.

This view had been supported by the late Lieutenant-General G. Lewis, R.E., and was likewise in accordance with those expressed by Captain Emile Maurice, a Swiss Engineer, in a work published by him in 1851, and since reprinted, in extenso, in the Professional Papers of the Royal Engineers.[1] If this position were correct, it would appear necessary that the attention of the authorities should be more immediately directed to the protection of the approaches to the Metropolis, by means of earthworks and entrenched camps, rather than to expending large sums in unprofitable fortifications on the land side of distant ports.

The importance of protecting the seaboard of the ports and arsenals must be generally admitted; but the loss of one of them could not be compared to the serious injury which the capture of the capital would cause. Without entering into a detail of the measures for the defence, or protection of London, it would suffice to point to the comparative economy and rapidity of construction of earthworks, both for advanced works and for entrenched camps, the latter being pre-eminently calculated to afford protection and support to irregular troops, such as the volunteer corps; and which might, moreover, during periods of peace, be made available for giving effective training to the latter valuable force.

He would observe, that in the construction of these earthworks, the co-operation of Civil Engineers would be of most efficient service, and during the period of peace, the commanding points should be occupied, and the forts and works, decided upon, should be constructed.

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[1] *Vide* "Papers on subjects connected with the Duties of the Corps of Royal Engineers," vol. ii. N.S. 8vo., p. 105.

Mr. T. ASTON observed, that it was impossible to hear the very able statements of Sir William Armstrong, with regard to the system of artillery he had had the good fortune and the great merit of introducing, without seeing how apposite had been the introduction of the question of rifled artillery, in connection with this discussion. The subject of national defences must be considered in connection with the question of what kind of artillery was to be employed, in arming those defences; this was a paramount question, which, in the first instance, demanded especial attention. For this reason, all must have listened with great interest to the explanations which had been given.

There was an allusion of a somewhat personal nature, made by Sir William Armstrong, referring to Mr. Whitworth, who, if he had been able to be present, would have replied more suitably than Mr. Aston could pretend to do. Mr. Whitworth would feel a gratification in acknowledging, with Sir William Armstrong, that during all the circumstances of competition,—as it should be called, rather than rivalry,—there had existed, and still did exist between those two gentlemen, feelings of friendship towards each other. Circumstances, not inclination, had placed those two gentlemen in positions of apparent rivalry, which they had not sought individually. Sir William Armstrong had made some statements, relative to the proposed comparative trials of which so much had been heard some time ago, but of which nothing had been heard latterly. He alluded, of course, to the proposed trials between the Whitworth and the Armstrong guns. Sir William stated, that he had been, on all occasions, anxious that those trials should take place. Now as Mr. Aston happened to be in a position to know all that had occurred with reference to those proposed trials, he could say, on the part of Mr. Whitworth, that he had always manifested and he still felt the greatest desire that they should take place. There was not any apparent reason why they should not have been decided. Mr. Whitworth accepted the programme drawn up, apparently, by the Ordnance Select Committee, and he only suggested, that his gun should be worked by his own men,—that the trials should be witnessed by disinterested persons,—and that the results obtained should be recorded and made public. These were certainly very reasonable conditions for Mr. Whitworth to propose, and they were equally reasonable conditions for Sir William Armstrong, or the Ordnance Select Committee, or whosoever had the disposition of the trials, to have accepted. Still they were not accepted, and though there had been private comparative trials, which he had reason to believe were in favour of the Whitworth guns, the public trials proposed had not taken place.

Although Mr. Aston had not authority to make any propositions on the part of Mr. Whitworth, he knew so well what that gentleman's feelings were, that he would not hesitate to say openly before the Meeting, that if Sir William Armstrong was prepared now to accept the proposed trials, he could answer for it, that there would be no opposition, but on the contrary, every facility would be afforded, on the part of Mr. Whitworth, for carrying them out. He stated this, knowing what had really occurred, and feeling sure that Mr. Whitworth would willingly receive any proposition, emanating from Sir William Armstrong, which could be reasonably accepted.

Having said thus much upon personal matters, which he had rather unwillingly entered upon, he would venture, at the risk of treading upon ground which would be much better occupied by other gentlemen in the room, who were more competent to deal with the subject, to allude to the observations of Sir William Armstrong, in reference to the materials employed in the construction of artillery. It was, without doubt, true, that the principle of using welded coils of wrought iron, had been carried to very great perfection, in manufacturing the Armstrong artillery. In the small guns, and it was said also in the case of some of the large ordnance, the coil system had been found to answer. But in very many instances, where that system had been employed for larger ordnance, it had been found to fail. No public statement had ever been made, nor did Mr. Aston mean to inquire, as to what proportion of the large Armstrong guns already supplied, had been found defective. There was no doubt of one fact, (which, indeed, Sir William Armstrong had himself admitted at that Meeting,)—that great difficulties were encountered in carrying out that system of manufacture, and many obstacles had yet to be overcome. Great merit was therefore due both to the contriver of the system, and to the able assistants, who gave practical help in carrying it out, especially at Woolwich. While venturing to speak on this subject, Mr. Aston would claim no more practical knowledge than that which any one of ordinary observation might acquire, who had the opportunity of seeing what others were doing. Having witnessed the use of homogeneous iron, in cases where its use had been most successful, he would claim for it, (notwithstanding there had been instances where it had failed,) the same forbearance of judgment, if he might use the term, which had been so willingly accorded to the coil system. With regard to small arms, there could be no doubt, that the use of homogeneous iron was a perfect success. He had seen it tried, under circumstances where it was tested as severely as it was possible to test any metal, and it had successfully withstood the trials. For rifled small arms, and for rifled ordnance, up to a certain weight, the same material had always been found to answer admirably. He admitted, that it was necessary, in dealing with it, to eliminate from it those inequalities, which, if not properly treated, might show themselves and cause failure; but he believed, that with a proper system of forging and of annealing, those difficulties were to be overcome. In the case of the barrels of small arms and of rifled field artillery, it was done with certainty, and by employing a more perfect system of manufacture, by using heavier welding machinery, and paying great attention to the process of annealing, he believed the difficulties attending the employment of homogeneous iron, for very large ordnance, would be vanquished. At least there might be claimed for it, at this moment, due consideration, until it had been fairly tested with a system of manufacture proportional to the scale on which the material was to be employed. As some proof that there existed good grounds for this position, he would allude to what was being done in Prussia. It was known, that Mr. Krüpp, of Essen, who should be ever mentioned as an early and very intelligent pioneer in the improvement of artillery, had been very successful in making guns with material of a somewhat similar character. He had, however, been obliged to employ apparatus of extraordinary power, when dealing with the material in large masses, and the results had, under such circumstances, been proportionally successful. But before it was advisable to make use of apparatus of great magnitude, and to incur the expense of erecting machinery capable of dealing with large work, it was necessary to take time and to count the cost. It might doubtless occur to many, that if it were only necessary, in treating this homogeneous iron, to forge it better and to anneal it properly, why was it not done? The reply was easy. All men having a practical knowledge of such matters knew how difficult it was to inaugurate a new system of manufacture, on a large scale, and no one would more readily admit this, than Sir William Armstrong himself; therefore the question could be readily answered, by saying that time and expense were elements which had to be considered in this, as in every other manufacturing question, as it was not every person who had Government resources at his command.

There was another point which must have been heard from Sir William Armstrong, with much satisfaction. That was a recognition of the muzzle-loading principle, as one which, under many circumstances, must ultimately be adopted. The muzzle-loading principle did away with a vast amount of complication. It reduced that which entailed great difficulty in manufacture, and great delicacy in management, to simplicity of manufacture, and safety of management; and, therefore, it was gratifying to hear it confessed by so high an authority, that, under certain circumstances, the muzzle-loading system must inevitably be recurred to. With regard to this newly-proposed system now explained and advocated by Sir William Armstrong, Mr. Aston could only say, that in several points it exemplified, in a remarkable degree, how possible,—nay, how natural,—it was, that two minds, pursuing the same course of discovery, should hit upon plans which, though not perhaps identical, yet nevertheless involved the same principle. It was stated, that in the shunt gun proposed by Sir W. Armstrong, the projectile, when it was pushed into the gun, entered with an easy fit, and that when it came out it hugged the tight side, and came out with a tight fit. Sir William likewise stated, that for two years he had been devoting his attention to working out this new principle, which was to take the place of his old principle. Now it was generally well known, that before the period embraced within those two years, that principle of having an easy fit for the projectile as it entered, and a tight fit as it left the gun, had been practically applied to Whitworth rifled artillery with great success. In some muzzle-loading guns which were still at Shoeburyness, and which had been there four, or more years, that principle was most successfully carried out. He alluded to the brass field-guns rifled by Mr. Whitworth for the Government, and tried at Shoeburyness some years ago. He did not, for a moment, wish to say, that Sir William Armstrong had been guilty of a plagiarism, but it was evident that the same principle had been adopted, whether knowingly, or otherwise, by two minds. To what extent it had been worked out in a similar, or dissimilar manner, he must leave to the opinion of those who were familiar with both the systems, and doubtless they would form their own judgment. A contrivance had also been mentioned, by which the escape of the gas was prevented; it was based upon the principle of employing a thin iron, or tin case, which was inserted in the breech end of the gun. Now this bore a very close resemblance to the metallic cartridge, which had been so long used by Mr. Whitworth, and had proved so efficient in his breech-loading guns. Again, with regard to the closing of the vent, by means of the sliding guard, which had been explained to the meeting. Many gentlemen present had seen a rifled breech-loading cannon, wherein a similar slide connected with a screwed breech-cap, was employed; it was used to cover the vent when the piece was not ready to be fired, and it was withdrawn only at the time when the breech piece was 'home,' and the gun might be safely discharged.

Mr. Aston alluded to these matters, to show how, in these three instances, two minds appeared to have travelled one after the other in the same groove, with the desire of effecting similar objects.

The system of muzzle-loading rifled artillery, properly carried out, would no doubt, to a great extent, simplify the arrangements that must be made, for arming the national defences of the country; and whether Sir William Armstrong carried out his new system, or another principle were adopted, it was to be hoped, that a speedy decision would be arrived at, by those who had to settle the question, and that the system adopted would be so efficient as to give general satisfaction to the country.

Mr. J. A. LONGRIDGE said, that having taken a considerable part in the discussion on the subject of artillery, in the last Session, he was glad to have an opportunity of adding a few observations, after the speeches of Sir William Armstrong and Mr. Aston. At that late hour he should best consult the convenience of the members, by making these observations as short as possible, and he must, therefore, leave much unsaid, which he could have added in support of his views.

The first question to be settled was, what was the power of artillery? Until it was known, what artillery could do, it was useless to talk about invulnerable ships and impregnable forts. He quite agreed with the remark, that had been made during the discussion, that the country had never as yet seen a really large rifled gun. He did not call either Sir William Armstrong's 7-inch gun, or Mr. Whitworth's 6-inch gun large guns. He had ventured to say, last Session, that upon the systems, which Sir William Armstrong and Mr. Whitworth then stated they were adopting, they could never succeed in making an 8, 10, or 12-inch gun. Perhaps he had gone a little too far, in saying, that they would never succeed; because, by dint of long-continued experiment, they might possibly, in time, hit upon the right dimensions to be given to the hoops, or rings; but he submitted, that he was substantially borne out, in the assertion which he made, by the result of Sir William Armstrong's subsequent operations. It was now twelve months since the subject had been discussed in that room, and he believed he was justified in saying, that Sir William Armstrong's 7-inch gun was even at the present time only an experiment. The question put to Sir William, by the President, respecting the initial velocity of the projectile, from this gun, was a most pertinent question; but it could not be answered, because the facts had never been ascertained. The gun had never been so tried as to prove its strength, or value. It was useless to talk of a velocity of 1,000 or 1,100 feet per second, out of the 12-pounder. He would not be satisfied, till something like the same velocity was obtained from the rifled gun, that was got from a round-shot gun. There must be a velocity of 1,800 feet per second; and to obtain that, there must be a strong gun, with little windage, and a quick-burning powder. It was quite possible to make a gun which would give that velocity.

He had not any wish to unduly praise his own system, but he must say, that the mathematical investigation, upon which that system was based, had never yet been disproved. No objection was raised to the principle at the discussion last Session, except that it involved mechanical difficulties in carrying it into effect. Had any effort been made to overcome those mechanical difficulties? He stated, last Session, that the difficulties existed only in imagination, and that he was prepared to point out the means, by which they could be met. He had never been asked to do so. He therefore reiterated that assertion at the present time, and he further affirmed, with the utmost confidence, that he could make a 15-inch gun, which should send a shot, 3 feet long and 15 inches diameter, in at one side of the 'Warrior' and out at the other. He might further state, that Captain Blakely did offer to make such a gun at his own expense, upon one condition only,—that it should be tried within three months from the time of its completion. That offer was not accepted. He wished to try the experiment of firing such a shot, not through the 'Warrior' itself, but through two sets of iron plates of the same thickness, and placed at the same distance, and fixed in the same manner as those of the 'Warrior.' He might also mention, with reference to the proposed contest, between Sir William Armstrong and Mr. Whitworth, that Captain Blakely offered to accept any conditions, that the War Office authorities, or Sir William Armstrong, or Mr. Whitworth agreed to. Captain Blakely, moreover, offered to make the gun, with which he proposed to compete, at his own expense, to send it to Shoeburyness at his own cost, to pay for the powder and the shots used, and also to find the men to work it. That offer also was not accepted. He merely stated facts: he imputed no motives. There the facts remained. The investigation of the theory, upon which the manufacture of hooped and wire guns was based, had been laid before the Institution upwards of twelve months ago. The system had been carried into practice, with great success, and to a great extent, by Captain Blakely, and never, to this day, had it been disproved. He believed it to be as infallible as mathematics could make it. It was feasible to put upon the 15-inch gun, which he proposed, a strain of 30 tons to the square inch, internal pressure, and under that pressure no portion of the inner core, which would be of cast iron, would be strained to a tension of more than 2 tons per square inch. He now called upon those who disputed this theory to show where it was wrong. Till this should be done, he would say, that they were still in the infancy of artillery, and before invulnerable forts and ships were mentioned, it was necessary to see what artillery was to be brought against them. It was all very well for Sir William Armstrong to ask, as he had done that evening, "to see it done." He would, in return, ask "to see it tried." As he had said before, Captain Blakely offered to do it, and with what result? He feared to appear dogmatical, but time did not admit of argument.

Before he sat down he would say a few words upon another subject, which was almost as important with regard to the national defences, as was artillery, viz., Electric Telegraphy. During his absence abroad, a long discussion had taken place before the Institution, upon the subject of submarine telegraph cables,[1] and a feeling was expressed, that their success had been interfered with by difficulties rather of a moral, than of a mechanical character. He quite agreed with that remark; and as time did not permit him to enter on the subject, he must confine himself to a simple protest against the course which had been adopted, with regard to the electric cable originally intended to be laid between Falmouth and Gibraltar, then transferred to Singapore and Rangoon, and now proposed to be laid between Malta and Alexandria; because, he asserted, that, as a national defence, it would be useless, and, as a scientific experiment, it would be utterly without value. It was proposed to lay along the shallow shores of Africa, a cable which was originally designed for deep waters, and the cost of which, before leaving this country, would probably be not less than £250 per mile; and it was also proposed to have two intermediate stations, between Malta and Alexandria, on territory over which England had no control. He did, therefore, protest most emphatically, against this proceeding, as a monstrous waste of public money, and a scarcely less enormous scientific blunder.

Mr. G. P. Bidder, jun., said he would not trespass long, upon the time of the Meeting, in availing himself of the privilege of reply upon this discussion, because, as would be recollected, he started with a determination to intrude his own opinions as little as possible, and, therefore, he had but little to answer, or to substantiate.

The first question of importance was that of the Coast Defences, and he must ask permission to explain one statement, with reference to that question; that was, that the sum of £12,000,000 had been voted for the purposes of coast defences. He confessed he was somewhat astonished at the very emphatic denial, which was given to that statement, by one of the speakers, and he thought there must be some misunderstanding between that gentleman and himself, or that they had been alluding to different things. He had since referred to the Report of the Defence Committee, which was signed by Colonel Jervois himself, and at page lvi of that Report he found, that the estimate made by the Committee of the cost of the works recommended, was £11,850,000, which was very near indeed to the £12,000,000 he had mentioned.[1]

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[1] *Vide* page 26 *ante*.

Colonel Jervois asked permission to explain, that the total estimate of the Commission was £12,000,000, which sum included the completion of works already in progress, £1,000,000 for floating batteries, and £500,000 for armaments. But, although £12,000,000 was the total estimate of the Commission, new works to the extent of £5,000,000 only had been sanctioned by Parliament. The statement in the Paper was that £12,000,000 had been voted. This was not the case.

Mr. Bidder, jun., resumed; he had understood the gallant Colonel to say, that £5,000,000 had been recommended by the Committee and that £2,000,000 only had been voted by Parliament.

There was one point in the discussion, which had been very much pressed. That was, that the Channel fleet ought not to be tied and fettered to the duty of protecting the ports of the kingdom. Now that seemed to be confusing two distinct questions. No doubt it was requisite, in times of emergency, that the Channel fleet should be free to act in any quarter, where it might be required; but the fleet, for the protection of the harbours and ports, was not necessarily a Channel fleet, but an independent fleet; and instead of fettering the Channel fleet, it would, of course, be at such times an additional and very valuable resource. The sum of money which would be spent, whether it were £12,000,000 or £5,000,000, upon these works, before they were completed, would be sufficient to equip a fleet which would be efficient for all purposes. If the £12,000,000 were taken at £4,000 per gun, it would furnish a fleet of three thousand guns.

There was one other point to be noticed. Supposing one of these ports to be fortified, both seaward and landward; if the enemy captured that port, it must be supposed, that he would occupy that as a position, and the very strength of the fortifications might make it difficult to dislodge him, which would not be the case, if the ports were protected by ships, because the ships would not afford any position to the enemy.

There was again another point. The money spent in the construction of land forts, for the protection of isolated points along the coast, was to all intents and purposes money sunk uselessly, as far as the protection of the country generally was concerned; for unless the enemy chose to attack those points, the fortification of them was useless. But it was not so, with regard to the money expended upon ships; because if ships were not required for these points, they might be removed to other places, where they would be required, or be employed on other services, which the emergency might demand.

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[1] *Vide* "Report of the Commissioners appointed to consider the Defences of the United Kingdom" &c; Folio. London. 1860.

Upon the subject of iron plating of vessels he wished to offer a short explanation. Captain Moorsom had said that he did not understand the expression made use of in the Paper, that iron plates added to a ship must tend to diminish its efficiency in other respects. What was meant was this;—If to a ship of war, of any size, there was added an armament of iron plates, a great weight was, at the same time, added to the tonnage which the ship had to carry; consequently it was essential to give to the ship coarser lines and a broader section, and thereby the speed of the vessel must be diminished, and he must maintain, that the diminution of the speed would certainly diminish the efficiency.

Another question had been raised, as to the advantage of constructing ships with a single deck, instead of two, or three decks. He was disappointed that the question had not been more prominently taken up in the discussion, because he considered it of considerable interest and importance. He would assume a case in point. Take two ships of two decks: suppose them to be both built on the same model; then cut one deck off one of those ships and make it a single decker. There would certainly be only half the number of guns, and in that respect she would be only half as efficient as the other vessel: but at the same time her height out of the water would be reduced by nearly one-half; consequently, at long ranges, the probability was that the per centage of shots, which would hit that vessel, would be only half that which would hit the other ship, which was higher out of the water. Therefore as long as she remained at long range she was as efficient a vessel as the other, because, although she might be able to fire only half as many shots, only half the per centage of the shots fired from the enemy would strike her. Moreover she required a smaller number of men to work her, and would cost considerably less in construction, and the superincumbent weight removed, by taking off her upper deck and guns, might be employed in arming her sides with iron plates. He was aware, that this argument might seem fallacious to those who remembered the old two and three-deckers of the last war, as in those days a two-decker was not a match for a three-decker; but the case was different now. Formerly, from the small size and inferior destructive powers of the guns used, men-of-war ranged close alongside each other, at such a distance that almost every shot would strike, and they could pound away at each other for hours, and the ship with most guns generally proved the victor. But the case was much changed, at the present time, with the improved ordnance now in use; because, in all probability, future naval actions would be decided, not so much by the preponderance of power, as by scientific gunnery. Therefore, although a vessel might carry a smaller number of guns, if she had superior speed, to enable her to keep at a distance, she might be able to compete with a larger vessel, which could annihilate her if they came to close quarters.

What appeared to be required now, was to arrive at general principles, as a guide for the future; and as a general principle it must be allowed, that whatever was done, either at sea, or on the land, ought to be done, with the design of utilising and developing those materials and resources, which the country possessed in abundance, and of economising those which were given more sparingly. If that were so, it might be asked, whether the best way to effect that object was by constructing and maintaining expensive and numerous land forts, which required a large number of men to garrison them, or by constructing slow-going vessels, upon much the same lines and principles as were adopted twenty, or thirty years ago. Would it not be preferable to aim at improving the means of concentration of the troops, at any required points of the coast, by perfecting the system of communications on shore; and by constructing for the navy, vessels of superior speed, and heavier armament, with all those superior appliances, which the mechanical ingenuity of the country could suggest, and which no other nation in the world could produce with such skill and rapidity?

Mr. Bidder,—President,—said it would be generally admitted, that the discussion had been extremely interesting in its character, and had embraced subjects of great national importance. How far anything which passed within the walls of the Institution might have any practical effect elsewhere he could not pretend to say, but he was certain that no more important subject, than that of efficiently providing for the National Defences, could occupy the attention of this, or any other Society.

Perhaps the most convenient course for him to pursue, in closing the discussion, would be to allude first to the more prominent points which had been touched upon by those gentlemen who had addressed the Meeting.

Mr. Scott Russell had introduced the subject of the Naval Department. The principal point to which he directed attention seemed to be, that in whatever manner the fleet was composed, it was essential to continue the old national custom, of not staying at home, and waiting for the attack of an enemy; but that the British fleet should seek the enemy whenever and wherever he was to be found. That was a remark which addressed itself to the feelings of every Englishman, and one with which all present would agree.

The next remark was less in accordance with the President's views. Mr. Scott Russell thought it was necessary to continue to full-rig the vessels of the navy, because the French did so. Now it was not apparent why this principle should be adopted. If the full-rigging of vessels of war was a good principle in itself, the Admiralty authorities ought not to stop to consider whether it was done by the French, or by any other nation: if, however, on the other hand, it was proved to be undesirable to full-rig these vessels, such a course ought not to be pursued simply because any foreign nation had adopted it. In reality it was a question whether they could be said to have followed that plan. For instance, although at present there was little reliable information as to the details of the construction of the 'Gloire,' yet from what could be gathered from conflicting statements, it was very far from being a full-rigged vessel; on the contrary, she was very lightly masted. If that were the case, and if she had the speed which was attributed to her,—although it might not be quite equal to that which was anticipated from the 'Warrior,'—then, supposing the course to be in the teeth of a heavy head wind, as the 'Gloire' was fortified throughout her entire length, whilst the 'Warrior' was only fortified over about one-half of her length, and her spar-deck was not at all fortified, if he had a choice, the President would rather go into action in the 'Gloire' with a crew of Englishman to oppose the 'Warrior' manned by Frenchmen.

Colonel Jervois, who was so well known from the active part he had taken in the Report of the Defence Commissioners, had in his speech re-stated the arguments which had induced the Commissioners to arrive at their published conclusions. These were in effect, that although with seven, or eight hundred miles of coast line there was an aggregate of nearly three hundred miles upon which an enemy could land, and which it would be utterly impossible to fortify against a general invasion, yet it was most desirable, that the great naval Arsenals of Plymouth and Portsmouth, and especially the military position of Dover, should be fortified against sudden inroads. The ostensible reason for this was, that on the outbreak of a war Great Britain might be in the position in which it had been before,—it might be unprepared,—the fleet might be dispersed in various quarters of the globe, and therefore England might be subject to sudden inroad. For that reason Colonel Jervois argued, that these ports should be defended by powerful sea and land defences. Now it should be observed, that it was hardly fair to charge the country with being unprepared for war. It was not the country that was unready. Parliament had never refused to provide liberally for the naval and military expenditure. The unreadiness had always been on the part of those who had to give effect to the votes of Parliament; and the President repeated, that if with the great annual expenditure of this country, the army and navy were ever again caught in an unprepared state, the country ought to look to and render responsible those who had the administration of the executive departments. If however from that, or from any other cause, the country was found unready, then Colonel Jervois was of opinion, that these defences should be established; but at the same time he admitted that an effective invasion must be on a very large scale.

There appeared to be an inconsistency in the Report of the Defence Commissioners, which, it was evident, they did not realise at the time. A sudden and serious invasion could not be attempted, without the employment of a very large army. Now the various garrisons proposed by the Defence Commissioners would require a force of about 70,000 men. The moment that war was declared, it would be essential, from the very nature of the circumstances, that every one of those garrisons should be completed, and therefore an enemy with even a small squadron would prevent that concentration of forces spoken of by Colonel Lysons. There was then the fact, that 70,000 men would be required for garrison duty. It was true, as the Commissioners stated, that these would not all be regulars; but there must be more, or less of regular troops. During the whole time of the anticipated invasion, these 70,000 men must be kept in garrison, and they would all in time become de facto regular soldiers: now the special duty of volunteers should be to resist sudden invasion, and they could not be kept year after year on garrison duty, and therefore their places must eventually be filled up by regular troops.

Colonel Jervois then observed, that forts were more economical than ships. No doubt they were so, to a certain extent, inasmuch as forts were stationary, in one position, and the expense of engines and of wear and tear of machinery was avoided, and the forts need not be fully manned, until they were required. On the other hand a ship was a fort, which could be moved to any number of situations. There could not be any doubt, that fixed defences must be provided for the protection of the arsenals.

It was satisfactory to find, that the Defence Commissioners had arrived at the conclusion, that the forts at Spithead,—if any were to be placed there,—were to be wholly iron constructions, and that they would be erected, under the supervision of that Commission, upon the best and most scientific principles.

Then Colonel Jervois asked:—"If you are to have the command of the Channel, what is the use of volunteers?" The answer to this was obvious: the knowledge of there being some 200,000 volunteers, must regulate, to a great extent, the numbers of the invading force; and if an enemy could not invade this country with a less force than 100,000 or 150,000 men, the natural inference was, that he would think twice before he attempted it, if only on account of the necessity of such extensive preparations for the enterprise.

Mr. Hawkshaw then followed, with some observations which recommended themselves to the feeling of the Meeting. He stated, that forts could be made impregnable, and that ships could not be rendered so; and that iron, in combination with stone, was mechanically inadmissible in their construction. No doubt that was perfectly true. There must be a limit to the strength of the plating of a ship, but there was practically no limit to the strength of a fort; nor was there any limit to the weight and power of the guns which could be placed in a fort, but there must be a limit to both, in the case of ships. This was a practical observation of great value, to which the President would hereafter more fully direct attention.

Colonel Lysons eloquently observed, that as far as his experience went,—and there were few men who had more practical experience, having had the command of a regiment throughout the Crimean campaign,—his opinion distinctly was, that this country should apply its great mechanical and pecuniary resources to the perfect construction of the navy, and that fortifications might become an element of weakness, in a country like this, where the supply of troops was so limited, as compared with a country whose supply of soldiers was almost unlimited; because an invading force would never stop to regularly invest a fort, but would rush on as rapidly as possible to the great point of attraction, the Metropolis.

These observations were followed by some excellent remarks from Captain Moorsom, who also insisted that the attention of this country should be devoted to the improvement of its naval resources.

The Members were all interested in the explanation afforded by Sir William Armstrong, relative to the progress of his guns; and the manly feeling which dictated the throwing aside of all secresy, demanded the admiration of all who heard him. It was most satisfactory to hear his indignant disclaimer, that he had any part in preventing the trials that were to have taken place, relative to the results of his mode of rifling, as compared with that adopted by Mr. Whitworth. No doubt Sir William felt assured, that a fair trial would satisfy the public, as to all the improvements he had introduced, which had the elements of success in themselves; and if any competitive trials had shown that anything better could be done, no man would have received that verdict more willingly than Sir William Armstrong himself.

Sir William had expressed an entire want of confidence in homogeneous iron. The President could not concur in that view; he did not think that, at present they would be justified in saying, that homogeneous iron had ever yet had a fair trial and had been found wanting. He had received a letter from Mr. Krüpp, of Essen, accompanied by a communication from Colonel Petiet of the Artillery Commission of France, stating as the results of his experience with 12-pounder guns constructed of homogeneous iron, that they had been completely successful. Mr. Krüpp, stated, that in Prussia they had made guns of 8-inches bore, which had successfully resisted all the proofs to which they had been submitted. There could be no doubt, that in this country there had been some disappointment attending the manufacture of guns, of large calibre, of homogeneous iron. This however might be fairly attributed to the mode of manufacture. The machinery for working the iron in the large masses necessary for guns, was not suitable for the purpose; and until hammers of 30 or 40 tons were applied, it would not be fair to pronounce the condemnation of homogeneous iron, as a material for artillery; indeed they were not justified in rejecting homogeneous iron for guns, until the same experience had been gained, and the same attention had been bestowed upon that metal, as had been given, under Sir William Armstrong's superintendence, to his own peculiar mode of construction.

Sir William Armstrong had explained very lucidly the mode of operation of the shunt gun, and expressed his conviction of the adaptability of projectiles, with a soft metal coating, to guns of large calibre, and that they were even superior to the hard tool-prepared projectiles. That was de facto the question of the comparative merits of the systems of rifling adopted by Sir William Armstrong and by Mr. Whitworth, and upon which it had been hoped that the trials, which were proposed last year, would have afforded conclusive evidence. The President was bound to say, that his own conviction was in favour of the hard tool-prepared projectile; and for these reasons:—he had seen a great many experiments with Whitworth guns, he had examined carefully the results of numerous trials, and he had received, within the last few days, the results of some comparative experiments made with Armstrong and with Whitworth 12-pounder guns at Shoeburyness, by the Ordnance Select Committee; those results were highly interesting, and they pointed to suggestions of great importance in the science of artillery.

The document was a private Report issued by the Select Committee, and he had obtained a copy of it from Mr. Whitworth.

Sir William Armstrong observed that, it had never come under his notice in any form whatever.

Mr. Bidder,—President,—believed that it had been kept very quiet. He had seen the original Report, and in fact had ordered a fac-simile of it to be printed, for insertion in the Minutes. He hoped this Meeting would not suppose that he was making statements which could not be substantiated. This circumstance induced him to remark, that it was the duty of any Committee appointed by any Government department, not only to investigate most carefully a subject of this importance, but to record all their proceedings and the results they arrived at, and to publish them with authority, in order to satisfy the country. There was not any mystery, or craft in the science of artillery, and the results of the innumerable trials, that had taken place, ought to be made public. What had Sir William Armstrong himself stated in the course of the discussion? He said, that up to this moment the law of retardation, with reference to projectiles, had not been ascertained; whilst with the experiments of the last twelve months the facts might have been observed and the law could have been determined, with the greatest nicety.

Sir WILLIAM ARMSTRONG said there was a separate law for different descriptions of projectiles.

Mr. BIDDER,—President,—replied, that there were separate results; but there could only be one law for all projectiles. Therefore in the operation of rifling, two things had to be attained: in the first place the highest rate of initial velocity; and in the second place the projectile should be exposed to as little retardation, as possible, from the atmosphere. It would appear, from information supplied by Sir William Armstrong, that the initial velocity of the projectile, with the same charge of powder, was nearly the same in the Armstrong as in the Whitworth gun; but the retardation of the Whitworth projectile was less than that used by Sir William Armstrong.

The Report of the Ordnance Select Committee (facing page 510), would illustrate the President's views. The practice in each case was certainly beautiful; and it demonstrated a most material point. If the initial velocity was the same, and from the facts supplied it would appear to be so, still from some circumstances, —probably from the form of the Whitworth projectile,—it was exposed to a less amount of retardation. The law, as far as he had ascertained, would seem to be, that an allowance must be made of 1 per cent. loss of velocity, for every 100 yards traversed. He found from the result of the experiments at Southport last year, that with a 12-pounder gun, at 35° of elevation, the ball was thrown to a distance of about 10,000 yards, and the time of flight was 40½ seconds,—the longest period upon record. The importance then of this law of retardation could hardly be sufficiently appreciated.

Mr. Longridge was of opinion, that the experiments should be continued, until the means were attained of projecting the rifle bullet with the same velocity as a 68-pounder shot, from a smooth bore gun. There were however reasons why that could hardly be accomplished; either the gun must be of a length which would render it unmanageable, or it could not consume the charge of

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powder. The velocity of a 68-pounder shot was stated to be 1,700 feet per second, whilst the experiments with the Armstrong gun showed that the initial velocity of the shot was about 1,200 feet per second.

It must be borne in mind, that the ordinary 68-pounder shot, instead of losing only 1 per cent. of velocity in every 100 yards, lost 6 per cent., whilst after travelling 800 yards, the velocity of the rifled projectile exceeded that of the ordinary 68-pounder: and in point of fact the penetration of the rifled projectile, at a range of 4 miles, was more than that of the ordinary 68-pounder at 1 mile. This showed the influence of the force of retardation and the importance of reducing it, in projectiles, to the lowest possible amount.

With regard to artillery, it was most important to arrive at some defined notions as to construction and results; because the armament and construction of forts and ships ought to have reference both to the artillery they were to carry, and to the power of resisting the assault of the artillery to be brought against them. As far as present experience went, it was clear, that both ships and forts ought to be so constructed as to encounter artillery capable of projecting shot of 300-lbs. weight. As had already been remarked, there was hardly any limit to the weight and power of guns applicable to forts, but there must be a limit to the size of ships' guns, on account of the great weight of these large guns, and the encumbrance of the mechanical appliances necessary for working them.

Colonel Simmons expressed a strong opinion, in corroboration of that of Colonel Jervois, that it would be necessary to revert to the old experience, of the fleet not being ready at the commencement of a war; but he added an observation, which all must agree with,—that the consideration of the national defences must be taken up in a comprehensive spirit, and should be viewed with reference to all the contingencies which might arise. Whilst however expressing that opinion, Colonel Simmons coincided in the view of Portsmouth being the only place to be fortified. It must be presumed, that he meant with land fortifications, in addition to the sea defences. He also said the forts suggested by the Defence Commissioners must be manned by the army, whilst the coast defences would be protected by batteries. He expressed the opinion, that the works at Dover would be an element of weakness, inasmuch as they would require 10,000 men to garrison them, and the same observations applied to the proposed defences in the Thames.

Colonel Simmons had very properly said, that what should be principally aimed at in this country, should be concentration, and he expressed the opinion, that the great Government establishments were now wrongly placed in their present situations. In this he was quite right, for why the great manufactory of guns should be in such a position as Woolwich, which would be a precarious one in case of invasion, every one was at a loss to conceive; independent of its exposed position, greater cost was incurred, both for materials and for workmanship, than would be the case in corresponding establishments in the midland and the northern districts, where materials and labour could be obtained at much cheaper rates.

Mr. Aston made a few observations, explanatory of the reasons why the proposed trials between the Armstrong and the Whitworth guns had not been made, and he claimed for the homogeneous iron system the same indulgence that had been extended to other materials and modes of manufacture of artillery.

These were the main features of the discussion.

The President now came to the general question, and to the conclusions in his own mind, from reading the Report of the Defence Commissioners, and hearing the arguments of the various speakers during the discussion, as well as from such consideration as he had been able to give to the question itself. It appeared to him that this subject had always been approached, both by Committees and individuals, without taking into consideration what would be the state of circumstances under any given series of events. There were data which should be before the minds of all who considered this question. The first should be, that ships,—especially wooden ships,—were not adapted to cope with forts properly constructed. From the evidence of Captain Coles, given before the Commissioners appointed to consider the Defences of the United Kingdom,[1] it was apparent, that the fleet sustained a signal defeat at Sebastopol, and the ships were only saved from destruction by the accidental circumstance of their being enveloped in their own smoke, and by the calm state of the sea. The second point for consideration, was that no material of war, nor ships, nor buildings, were safe in any roadstead, or in any arsenal, within 7,000 yards of where a ship-of-war could manoeuvre. He did not mean that a fort would be attacked at a distance of 7,000 yards, but that everything within that distance should be rendered invulnerable. Keeping in view these two points, it was well to consider what would be the position of this country if one state of things existed,—which everybody desired,—which everybody admitted ought to be attained,—which was very possible,—and which doubtless would eventually be arrived at;—that was, the complete command of the Channel. It was only a question of when this would be attained.

It should be borne in mind that from the 'Skaw' on the northern extremity of Jutland, with the single exception of the Scheldt, there was not a single harbour along the coast, (including even Cherbourg,) in which everything could not be destroyed by a fleet having the command of the narrow seas. Having rendered all these positions untenable, the fleet would be able to put down all privateering; because privateers could not hold the sea in the teeth of a strong naval force, and in the absence of ports where privateering expeditions could be fitted out. A privateer of the present day must be a very different class of vessel to what it was formerly, and whilst every port in the Channel was watched by a steam fleet, there would be no place, where marauding vessels could be equipped. The experience of former wars showed, that although the channel swarmed with ships, although every description of vessel was afloat, yet privateers did steal out, in spite of all the vigilance exerted, and they injured the mercantile marine to a great extent. It would however be erroneous at the present time to refer to past experience. The circumstances were very different now. In former days, with a gale of wind from the south-west, the privateers could come out of their ports, whilst the fleet could not get at them, especially in a heavy gale from that quarter, which might last for a week, or a month. Moreover, as any small vessels could be employed in privateering, they could steal out with a fair wind, and disturb the commercial marine, almost without any risk to themselves. At that time everything was dependent on accidents of wind and weather. Now, however, other circumstances prevailed, and with a competent steam fleet; there was not a day, or an hour, when every part of the Channel might not be visited by ships-of-war of some class. The facilities afforded by steam must be taken both ways; if it enabled an enemy to come out of port, it also afforded to the British fleet at least as great facilities for keeping him shut up in port and for destroying him when he was there. There was, however, an instinctive feeling pervading all these Government reports, that this country ought to have,—in fact the Commission said, it must have, a fleet equal to any combination that might come against it.

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[1] *Vide* Appendix X., page 535.

A Channel fleet, it was argued, might be dispersed all over the world, and might not be at hand, in a case of emergency, and therefore land defences should be prepared, for preventing sudden inroads upon the coasts, and large sums of money had actually been devoted to that object. Now it was necessary to consider what that meant. If the fleet held the command of the Channel, the commercial marine was comparatively safe. It was in the Channel where the merchant ships would be chiefly picked up. No doubt a privateer would fall in with vessels in the Atlantic, or the Pacific; but looking at the cost and the difficulty of equipping a steam-vessel, as compared with a sailing-ship,—bearing in mind, that nothing but a steam vessel would be fit for privateering, in the present day,—and considering also the difficulty of getting supplies of coals in those remote quarters,—the chances of many steam privateers being fitted for distant services were remote; the Channel would, therefore, be the place where privateering must always be chiefly carried on. Therefore, if the command of the Channel was lost for a week, or a fortnight, or a month, the destruction of the mercantile marine, and the interference with sending supplies of coal to ships on foreign stations, would be such, that the post of the First Lord of the Admiralty, under those circumstances, would not be an enviable one, and there would be an exhibition of public feeling of a character too painful to contemplate, especially as the authorities would not have much sympathy from those who knew the dilatory management of Government affairs.

What, however, was the interruption to this supremacy, which the Defence Commissioners apprehended, and which induced them to ask for an expenditure of £12,000,000 of money, and for garrisons requiring 70,000 men? Portsmouth and the Isle of Wight alone would absorb £2,800,000 of the amount. It appeared to be supposed that an enemy making a sudden inroad upon this country would attack Portsmouth. Now it would take 50,000 or 60,000 troops to invest that port, by sea and land. That was a large force in itself; and it must occupy weeks, or even months, in assembling and bringing such a force across the Channel to invest that place. The Commissioners, therefore, evidently assumed that the fleet would be beaten, in the Channel, to an extent that would involve national ruin and a loss of prestige, which would not be recovered within two generations. Such would certainly be the case, if the command of the Channel was lost, even for a brief period. Whether this would be to such an extent as to permit the capture of Portsmouth, or any other arsenal, was a question, but it would end in the destruction of a large portion of the naval and military resources; and the enemy would take Alderney and occupy it for his own purposes. Therefore the question became entirely one of cost, and by that it must be examined, and no man would venture to say, that, if within a given estimate, the command of the Channel could be preserved, this country ought not to be in that position, which was a vital point. Now as to Dover, that place was fortified as a military position, and the expenditure upon it was estimated at £600,000.[1] The President would ask, of what earthly use Dover could be as a military position? There was not any harbour of refuge there yet,—perhaps there might be in 1960,—and then it would require to be defended. It was now only a tidal harbour, and no great invading force could either land there, within a reasonable time, or be collected at that point, for at times it was merely a dry harbour. Folkestone would answer the purpose of the enemy much better than Dover, and would open a more convenient road to London; so that, if there was anything in the position of the Defence Commissioners, Folkestone ought to be fortified as strongly as Dover. Again, where must the enemy come from to land at Dover? He must come either from Cherbourg, or from Brest. But why should they go out of the way to arrive at a place which was inaccessible at low water, and was defended by powerful military works, when there were so many accessible and undefended places on the coast, along which a fleet must pass, to knock its head against Dover, where the Commissioners proposed to locate a garrison of 6,000 men? This argument might seem to be hazardous, but it was borne out by the Report of the Defence Commissioners.[1]

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[1] The exact amount is £335,000 instead of £600,000.—Pres. Inst. C.E.

Upon the question of the cost of the proposed defences, the data afforded were of the most unsatisfactory description. A Commission was appointed last year, to inquire into the control and management of the Royal Naval Yards. That Commission reported, that there was not one single account that could be relied

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[1] Extract from the "Report of the Commissioners appointed to consider the Defences of the United Kingdom," page 53:—

"DOVER.

"REASONS FOR FORTIFYING.

"159. The questions that arise in considering the fortification of Dover, are in some respects of a nature dissimilar from those which have been discussed in treating of the places already mentioned. Dover does not contain either a dockyard or arsenal which it is necessary to protect from bombardment or capture. It is in fact the only place in England which partakes of the nature of a strategical fortress or intrenched camp in its primary object.

"The objection we have referred to in the opening part of this Report to the construction of fortifications purely for strategical purposes applies, therefore, in some respects to Dover; and if there were no works of defence or military establishments there already, it appears to your Commissioners that it would become a question whether that place should or should not be fortified.

"160. The considerations that have led to the construction of fortifications at Dover from time to time may be classed under three heads:—

"1. Being the nearest point to the opposite coast, the possession of the strong ground about Dover, which would give an enemy command of the harbour and roadstead, would afford him immense advantage, as a *tête de pont* under cover of which he could throw troops into this country.

"2. That if fortified effectually, Dover becomes a secure military position of great value with reference to the landing of an enemy upon any part of the coast of Kent, in the event of which he would be obliged to besiege Dover, or to mask it with a considerable force, in order to prevent the garrison of the place acting upon his communications during his advance. With this view, we understand that the plan of the commander-in-chief, at the time of the expected invasion at the beginning of this century, was to make Dover the *point d'appui* of his regular army, intending to upon,—that they could not arrive at the cost of any single transaction, not even the simplest of all, that of the building of ships. They however said, that they got something like it at Pembroke, where the cost amounted to £33. 9*s.* per ton. It might be considered a strong observation, but it would not be any exaggeration to say, that there was not a single figure, which had been presented to that Commission, which had not been 'cooked.' The reason for saying this was very simple: it would be recollected that ancillary to the possession of office, Lord Clarence Paget made a striking speech, in the House of Commons, with regard to the management of the navy. By one of those political incidents common to this Government, Lord Clarence Paget became an official of the Admiralty, but he would never be forgiven by the 'red-tapists' for that speech. The late Surveyor-General of the Navy, in particular, before that Commission severely criticised the remarks of Lord Clarence Paget, and in doing so he introduced a great number of figures to show that his Lordship was in error. Now it was easy to prove that all those figures were 'cooked.' The Surveyor-General gave £4,948,378[1] as the cost of constructing 209,408 tons of shipping in eleven years. If that had been an account which should guide the Commission, it ought to have been from actual transactions; but it was all pure surmise. The ships for which the sum of £5,000,000 of money was voted, were computed to cost £24 per ton; whereas the Commission, before whom that statement was made, reported, that they could not arrive at the cost of building a single ship, but that the approximate cost of building at Pembroke was £33. 9*s.* per ton. Now would any assembly of men of common sense receive such evidence as truth, or would they believe that such a statement, from such an authority, was entitled to the slightest confidence? Nay, it might be possible to go further, and to say that the whole Report of that Commission

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act upon the flanks and rear of the enemy, instead of manœuvring in such way as to cover London.

"3. The scheme for constructing a large harbour of refuge is an additional reason for fortifying Dover; and as it has already progressed to such an extent as to furnish some shelter, which would render it valuable to an enemy, and afford a good pier for disembarkation, it is one which holds good, even although the harbour project be not fully carried into effect.

"Weighing these reasons, and bearing in mind that extensive, although very imperfect, works of fortification already exist at Dover, and that certain improvements have been authorised by Parliament, your Commissioners are of opinion that no other course is open but to complete the works in progress, and to give the defences such additional strength as may be considered necessary to render them secure."

[1] *Vide* Appendix, No. 27 B, to 'Report of the Commissioners appointed to Inquire into the Control and Management of Her Majesty's Naval Yards:'—

	Tons.	Cost.
"Ships built (including those converted into screw-ships on the slip) during eleven years, from the 1st April 1848, to the 31st March 1859 .	209,408	£4,948,378."

showed, that the designing of the ships of the navy was under the control of those who were ignorant of the art they professed to practise. If a man was master of an art, he ought to be able to tell his employers what would be the result of that which he was going to do. A naval architect in designing a ship, for the merchant service, contrived to attain tolerably well the object in view. But in the Royal Navy, there were instances of 15 feet being put on to the bow, to ascertain what difference this addition would make, between her and another ship, built upon the same lines, not for any foreseen real practical benefit, but merely to ascertain whether 15, or 20, or 30 feet would give the proper lines; as if this could only be ascertained by a series of costly and wasteful experiments. In the "Minutes of Evidence taken before the Commissioners appointed to Inquire into the Control and Management of Her Majesty's Naval Yards," page 65, Rear-Admiral Sir B. W. Walker, said:—"The 'Howe' was ordered to be built in January 1855, and in December 1857 it was decided to lengthen her by the bow 15 feet, with a view of ascertaining, by actual trial with the 'Victoria,' a similar ship, the advantage which would be gained by finer lines. She was at that time in frame only. This is the only ship designed for the screw during the eleven years which has undergone any alteration. The actual expense of taking down the timbers, and retrimming and replacing them, was £384. 5*s.* 3*d.*" Now speaking in the presence of practical men who know pretty well the cost of altering anything on board a ship, the supposition that a line-of-battle ship could be lengthened 15 feet for the paltry sum of £384. 5*s.* 3*d.* was going a little too far. With such cases on record it was only reasonable to say, that the construction of the navy, and the management of the accounts had been in the hands of persons incompetent to discharge either one duty, or the other.

In reflecting how it might be possible to arrive at the cost at which an efficient navy could be maintained, it occurred to the President, that some elements for that purpose might be obtained from the records of the experience of some of the great public marine companies. He therefore applied to the Peninsular and Oriental Steam Company, and found that they possessed a fleet of 60 vessels in all, of which 52 were steamers. The gross tonnage amounted to 80,000 tons. The tonnage of the steamers was 72,000 tons, with engines of 17,500 H.P., and they navigated 1,400,000 miles annually. That Company had establishments not only in England, but also in Portugal, at Gibraltar, in Malta, and at Alexandria; they had also to pay heavy transit charges in Egypt, and then to maintain other establishments at Aden, Ceylon, Bombay, and Calcutta, and in China. They had to pay enormous prices for the fuel consumed in those Eastern seas;—

they had to maintain their fleet in a state of efficiency to perform stated duties; — to provide an insurance fund against losses,—as well as to make good all losses; and all this was effectively done for £2,200,000 a-year, with 80,000 tons of shipping, 72,000 tons of which were steamers. The Royal Navy afloat during the last four years constituted an annual aggregate of 370,000 tons;—including transports, guard ships, and every description of vessel afloat, down almost to dockyard lighters. Now 370,000 tons was a little more than four and a half times 80,000 tons, and that would amount to about £10,000,000 a-year for supporting a Navy of 370,000 tons afloat, navigating 6,000,000 miles annually. Comparing then the service required of the Royal Navy,—particularly the Channel fleet, which only in the summer time navigated once, or twice round the coasts of England,—and contrasting the expense of working ships under those favourable circumstances, with that of vessels which had to make their voyages in all weathers at fixed periods, it might fairly be asked whether the navy ought not to be managed with as much skill and be maintained at a cost comparatively not exceeding that of the fleet of a private company. In fact it ought to be done much better, as the Government ought to command the highest talent, and it should be used to produce a fleet which could defy the whole world.

After looking cursorily at these general points, the next questions were, what should be the class and mode of construction of the ships of the Royal Navy? Perhaps the best way of considering this question was to state what they ought not to be. Now taking the old three-decker, although perhaps it was hardly fair to take that class, for it had nearly disappeared,—but taking then the old wooden three-decker,—she was certainly not fit to attack a fort, nor was she fit to pursue a fast enemy; she was only fit to fight in line, against ships of her own size and of her own character. This could not be denied; but even taking the 'Duke of Wellington' of 130 guns and 1,200 men and having a speed of 12 knots; and supposing her to be encountered at sea single-handed, by a gun boat carrying two, or three 200-pounder rifled cannon and going 14 or 15 knots. Ask any sailor which ship he would rather be on board of, and which ship was likely to go to the bottom first, in an engagement? He would reply that he would prefer the gun boat. Much more if twenty of these gun boats attacked a fleet of 'Duke of Wellington's;' as they could, from their superior speed, concentrate their fire upon any portion of the hostile fleet and cripple it, before assistance could be rendered. It appeared to be agreed now, that the old wooden line-of-battle ship must be given up. Then came the question, what should be done with them? The simplest plan was to cut them down,—take off the two upper decks of the 'Duke of Wellington,' and there would be 1,800 tons taken off her weight, and this reduction would enable her to be fortified by iron plates of 4½ inches in thickness, whilst she could carry twelve very large guns, or thirty guns of somewhat smaller calibre. He would ask the naval officers present, whether they would rather be in the 'Duke of Wellington' cut down, or not; or fortified, or not? and he would venture to assume that their reply would be in favour of the cut-down ship, if they had the opportunity of making a choice.

If, as appeared most probable, guns throwing projectiles of 300-lbs. weight were to be used, the navy would be principally composed of corvettes, with the guns upon the spar deck, and a vessel carrying six such guns on each side would have a broadside of 1,800 lbs. of metal, which would be no wonderful disparity with the weight of broadside of the 'Duke of Wellington,' as she now stood. These corvettes must however be built upon the finest possible lines, so as to attain great speed. This induced the question of the masts and spars. The weight of the rigging of the 'Warrior' was stated to be not less than 180 tons. Now a vessel going 14 knots per hour had a head wind during nine out of ten days, and in going into action all her sails must be stowed away, as worse than useless; in fact they were a positive nuisance. The cutting away of a mainyard, or a topmast coming down upon the deck, would impede the working of the guns, and even in fair weather rigging was useless in the Channel. But if vessels did not require to be fully masted for the Channel, it did not follow that they should not be fully rigged for foreign service. In action every man's attention was required to be directed to the work of destruction, and it would appear that the less they had to do with the manipulation of spars,—particularly with the wreck of them,—the better the service would be performed. Then these ships ought to be built on the finest lines, and it was difficult to imagine why the late Surveyor-General persisted in using the bluff lines which characterized his vessels. Every one who had seen those ships propelled through the water must have been struck with the enormous power that was wasted by displacement. The reason urged was, that unless there was a good bearing at the bow the guns could not be brought forward for chasing. Now it was of little use chasing anything, which there was little, or no chance of overtaking, as must be the case with these bluff bows; but by altering the vessels so as to get 2 knots an hour more speed, and by holding a diagonal course, the chasing ship could bring the whole of her broadside to bear, and thus with a few very heavy guns become more efficient than with the present class of ships.

Strangely enough, in spite of all official obstruction, one frigate in the Royal Navy,—the 'Immortalité,'—was built upon good lines; her bow was a great improvement upon the old form, but still she had not the complete clipper lines. It would, however, scarcely be believed, that having a finer bow, the masts were put in the same relative position as in the case of the old-fashioned bow! The consequence was, that the vessel was down by the head, when she was tried.

Another point of importance was, that all these vessels should be as near as possible of uniform speed; and with all due deference to the authorities, it did seem to be ridiculous, that the Government was one day building a vessel like the 'Warrior' with very fine lines and great power, with a speed of 14 knots, and on another day constructing a vessel, less in size, less in power, and with a fuller bow. Such vessels could not possibly act together, and the 'Warrior,' unless she travelled slower than she was built for, could not be of any use in consort with the smaller vessels.

There was another point which had never yet been adequately considered, although strong evidence was given upon it before the Defence Commissioners:—that was, as to the use of Steam Rams. Captain Sulivan expressed a strong opinion upon that subject.[1]

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[1] *Vide* "Evidence taken before the Commissioners appointed to Consider the Defences of the United Kingdom," page 16:—

"190. (*Chairman.*) A ram would require a considerable depth of water, would she not?—No; I do not think that she need draw very much. I believe that all vessels would or ought to be used as rams. I believe that actions might be decided a great deal in a future naval war by running down; so much so that I have a great objection to seeing all these cutwaters put up in our ships. I have urged privately that all our ships should be built without cutwaters, with upright stems; that naval actions may be decided by running down with much less loss of life than by any other means; and I proposed the first day I ever joined Admiral Napier in the Baltic, that if there was a chance of meeting the Russian ships at anchor outside, they should be attacked by cutting off the cutwaters of the ships, and taking their bow-sprits out, and securing their lower masts, and by running down, without firing a shot, that they should run in on their broadsides, and I believe that that would destroy any line of ships with perfect impunity which were at anchor, and that you could take the broadside in that way under any fire which they could pour on you. Therefore, I believe that all our ships ought to be prepared for running down ships in action, whether iron-cased or wooden; and it is known that a very small vessel has the power to destroy one of our largest ships by that means.

"191. (*Sir Frederick Abbott.*) Would she not sink herself?—There is not the slightest fear of it. I may mention a case which occurred not long before I went to the Baltic, which I mentioned at the time:—a small iron mail steamer of 400 tons, coming up the Thames, ran stem on to the broadside of an American liner of 2,000 tons; she drove her bow through the bilge of the American liner until the stem brought up in the combings of the main-hatchway of the ship, and when she backed out, the large 2,000-tons ship went down instantly, and the bows of the little 400-tons iron ship were scarcely injured. I also know that the 'Talavera,' a small 74, some years since, only going 5 knots under sail, ran into the beam of a new 60-gun French frigate larger than herself, and the result was that she nearly drove her side in; she drove some of the beams right out on the opposite side, and the ship was with difficulty kept afloat till she was brought into Sheerness. Therefore, if at 5-knots' speed under sail a ship would injure another ship like that, there is no question what the result would be in a naval action. The projecting cutwater cuts into the upper works first, which saves the side under water; whereas had there been no cutwater, that ship must have gone down at the moment.

In substance he said, that if he sailed out from Spithead to attack an enemy, the first thing he would do would be to cut away his figure head and work his vessel as a ram. The object of a ram was to use it against the transports of an invading force, which might thus, with certainty, be run over and destroyed, and so to create an amount of panic which might neutralise further attempts at invasion. The question was how these rams should be constructed. It was the impression of some persons, that they should be rather slow vessels; but it was difficult to see of what use a slow vessel would be, when employed against fast ones. It rather appeared, that they should be very fast vessels, and be constructed for no other purpose than as rams, so that only a few men would be required to manage them, and but few human lives would be exposed to risk in that special service. Now it appeared to the President that three, or four of these vessels, stationed in the Channel, would at all events have a useful moral effect upon the mind of any intending invader. But to render these ships effective, there must be harbours both of rendezvous and of observation. Here it must be remarked, that although nearly a million of money had been spent upon the so-called harbour of Alderney, and a million more upon Jersey, the former had scarcely been used, except by a couple of French cruisers, for the last four, or five years, and the latter for an insignificant local traffic; yet next to nothing had been expended upon the east coast of England, which was most important to the great coal trade of the country. Therefore he would urge, that there should be at least two harbours of observation and of refuge situated in proper positions, —say probably at Orfordness and at Flamborough Head. If the money already uselessly spent at Alderney, had been devoted to those purposes, it would have represented a commercial value, and have afforded eventual security to this country.

Having now, although imperfectly, gone through the principal topics that had been brought forward, the President would again repeat the conviction, that it was essential,—and he was sure it could be done with greater economy than was now practised,—that the country should be placed in a position of defence, equal to any emergency, and so as to maintain the entire command of the Channel. The defences of the seaports should be sea defences and not land fortifications; the few forts to be constructed should be upon the most scientific principles—not circular redoubts, which were mere

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" 192. (*Chairman.*) To do away with the cutwater, must you not have sharper bows?—Not in the least; the present cutwater is only a false bit put on. If I was going out of Portsmouth to-morrow, in command of a squadron, in case of war, I would, the night before I went, saw through, on my own responsibility, all the figure heads and cutwaters, and let them drop off, and secure my foremasts so as to use my vessels in running down."

shell-traps, and slaughter-houses. The suggestion of Mr. Hawkshaw should be adopted, that what was done should be executed in the best possible manner; either having complete iron forts, which might be made impregnable, or else being content with Mr. Fergusson's system of earthworks. Upon this latter subject it had been expected that some decided evidence would have been given before the Defence Commissioners. The President would only add, in conclusion, that if the means which were so liberally voted for the naval and military branches were only administered with skill, honesty and judgment, this country had resources within itself which would enable it to resist, successfully, the combined efforts, not only of all the nations of Europe, but of all the nations in the world.

Sir WILLIAM ARMSTRONG expressed a hope, that he should have an opportunity of criticising the figures which had been referred to by the President in his observations.

Mr. BIDDER,—President,—said, nothing would be so agreeable to him as that both Sir William Armstrong and Mr. Whitworth should give the Institution complete Papers upon the subject of their systems of artillery, and that they should be discussed as fully and as freely as this subject of National Defences.

Sir WILLIAM ARMSTRONG acknowledged the moderation with which the subject had been treated by the President; but he must be allowed to remark, that matters of fact upon controversial questions were better introduced during the discussion, than during the summing up. The worthy President stood very much in the position of a judge,—a very able one,—and the Meeting was in the position of a jury—a most intelligent one, he admitted—but he thought it was at variance with the custom of their proceedings to introduce into the summing up new matters of fact which had not been previously before the Meeting.

He would supply for publication some explanatory documents, which might form part of the Appendix to the discussion.

Lieutenant-Colonel JERVOIS must take exception to the statement of the President, that a sum of £600,000[1] would be expended upon works of fortification, at Dover. That statement was not corroborated by the Report of the Defence Commissioners. The expenditure recommended by the Commissioners for works at Dover was £170,000; that sum, added to £165,000 for works already in progress before the Defence Commissioners reported on the subject, made a total of £335,000.

What Colonel Jervois had said was, that an expenditure of £5,000,000 was all that had been sanctioned by Parliament for new works recommended by the Commissioners. There was a great difference between £12,000,000, or whatever the sum might be, being estimated by the Commissioners, and it being actually voted by Parliament. The statement in the Paper was that "about £12,000,000 had been recently voted." That was not the case. It was to be observed, that £1,000,000 of the amount of the estimate of the Royal Commissioners was for floating defences, and the sum of £500,000 was for armaments.

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[1] *Vide* previous note, page 514.

Mr. Bidder,—President,—said it was all very well for the gallant Colonel to fix upon that particular matter. He might rely upon the President justifying the figures he had quoted, and he would print extracts from the Report itself.[1] With regard to what had fallen from Sir William Armstrong, he would remark, that he conceived it to be the duty of the President of the Institution, to throw as much light as he could, upon any subject that was brought before it. The object had been not only to elicit discussion, but to induce the production of other Papers and communications upon the same subject, and he could only express a hope, that during the next session the Institution might be honoured with a Paper from Sir William Armstrong, fully explaining his views and giving a history of his system, from the commencement to the present time.

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[1] *Vide* Appendix IX., page 534.

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I.—**Report** of Ordnance Select Committee on Practice with **Armstrong** and **Whitworth Guns**, alluded to by the President, page 510.

3759 { 1671 B. **Armstrong's** B. L. 12 pr. Gun, *versus*
1943 C. **Whitworth's** B. L. 12 pr. Gun.
With reference to *Minute* 3625. Report of Practice submitted.
Object.—To ascertain range and deflection of Whitworth's B. L. 12 pr. Gun, in Comparison with Armstrong's 12 pr. Gun.

Date.	No. of Rounds.	Charge.	Elevation.	Armstrong's 12 pr. B. L., No. 6. Weight . . . . 8 cwt. 2 qrs. 11 lbs. Length . . . . 7 feet 6 inches.[1]						Whitworth's 12 pr. B. L., No. 1. Weight . . . . 9 cwt. 3 qrs. 0 lbs. Length . . . . 8 feet 8 inches.					
				Range.			Mean diff. of Range.	Mean observed Deflect.	Mean Time of Flight.	Range.			Mean diff. of Range.	Mean observed Deflect.	Mean Time of Flight.
				Min.	Max.	Mean.				Min.	Max.	Mean.			
		lbs.	degs.	yds.	yds.	yds.	yds.	yds.	seconds.	yds.	yds.	yds.	yds.	yds.	seconds.
1861 2nd April.	5	1·50	2	1108	1150	1130	12	4	3·4	1159	1223	1198	19	1⅓	3·5
,,	,,	1·75	,,	1226	1307	1256	26	5	3·6	1266	1314	1289	28	1⅔	3·4
,,	,,	1·50	5	2128	2165	2146	11	9	6·8	2072	2486	2367	119	1⅓	6·9
,,	,,	1·75	,,	2331	2399	2358	15	11	7·3	2335	2644	2471	97	1⅔	7·0
,,	,,	1·50	10	3512	3597	3568	24	12	9·8	4137	4318	4222	68	3	10·2
,,	,,	1·75	,,	3866	3961	3908	41	17	12·9	4348	4449	4399	25	6⅔	13·1

Elevation by Quadrant. Guns mounted on Travelling Carriage, on Lieut.-Colonel Clerk's Platform.
Armstrong's Gun. Wads choked in Cartridge.—Whitworth's Gun. Powder and Wad contained in Tin Case.
Weight of Wad, 2 oz. 4 drms. Weight of Tin Case, 8 oz. 8 drms.

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[1] The length, according to Sir W. Armstrong, should be 7 feet.—**Editor.**

II.—LETTER from Sir W. G. ARMSTRONG to the President, June 10, 1861.

"9, *Hyde Park Street, W., June 10th,* 1861.

"SIR,

"I BEG to enclose a copy of Correspondence between the Secretary of Ordnance Select Committee and myself, relative to the table of practice with Whitworth and Armstrong guns, which you read in your concluding address at the Institution on the 28th ult.

"I shall feel obliged by your appending this correspondence, with the annexed particulars of practice, to the Report of the Proceedings, that being the only means by which I can give the necessary explanations.

"I am, Sir,
"Your obedient Servant,
"W. G. ARMSTRONG.

"*The President of the Institution of Civil Engineers.*"

III.—LETTER from Sir W. G. ARMSTRONG to the Secretary of the Ordnance Select Committee, June 3, 1861.

"8, *Great George Street, Westminster, June 3rd,* 1861.

"SIR,

"AT a meeting of the Institution of Civil Engineers on Tuesday last, the President read a printed statement obtained by Mr. Whitworth from the Ordnance Select Committee, and containing, in a tabulated form, the results of recent comparative trials made at Shoeburyness with Whitworth and Armstrong guns.

"In that statement there is a column headed 'mean observed deflection,' which was naturally, though erroneously, treated by the President and understood by the meeting as indicating lateral error. I need scarcely say that in any statement of this kind it is necessary to discriminate between irregularities of deflection which alone constitute lateral error, and deflections of a constant nature, arising from side wind and other causes, which admit of correction in laying the gun. But in the present statement no such distinction is made, and the figures, so far as lateral error is concerned, are consequently entirely delusive.

"To enable me to correct the erroneous impression which the publication of this document will convey, I must request the Committee to place at my disposal, without any restriction against publicity, a detailed report of the practice, accompanied by a comparison of error expressed in rectangles, according to the method usually adopted by the Committee.

"I have also to express a hope that since the Committee have put these guns into competition in regard to accuracy and range, they will proceed to make a complete comparison between them on every point of efficiency, including that of destructive effect, which ought to be the first consideration in judging of a gun, and the projectile for which it is adapted.

"In conclusion, I may be allowed to observe that it would be better to publish the results officially and in full, rather than allow them to transpire indirectly and in an imperfect form.

"I have the honour to be, Sir,
"Your obedient Servant,
"W. G. ARMSTRONG.

"*The Secretary to the Ordnance Select Committee.*"

IV.—LETTER from Colonel LEFROY, Secretary of the Ordnance Select Committee to Sir W. G. ARMSTRONG, June 4, 1861.

"*Ordnance Select Committee, Royal Arsenal, Woolwich,*
"*June 4th*, 1861.

"SIR,

"Having submitted your letter of the 3rd instant to the Ordnance Select Committee, I am directed to observe that the printed statement to which you refer, as having been read by Mr. Bidder at the Institution of Civil Engineers on the 28th ult., appears to have been the accompanying table extracted from the proceedings of the Committee, a copy of which was given to Mr. Whitworth at his request on the 14th ult. I have already furnished you with the same table with the additional information requested in the letter under acknowledgment, viz., the lateral error, after subtracting the effect of wind, &c., and the comparison by means of rectangles, showing the area which would include one-half the shots, both laterally and longitudinally at each angle of elevation. The table furnished to Mr. Whitworth contained the column headed *Mean Observed Deflection*, but did not contain the reduction to a mean line—a circumstance which was pointed out at the time to Mr. Whitworth. I have also furnished you with the details of the practice with both guns.

"With respect to the use you may desire to make of this information, the Committee see no objection whatever to its being made public if permitted by the Secretary of State; they are not themselves empowered to authorise publication.

"With reference to your request that the Committee will now proceed to make a complete comparison between the guns on every point of efficiency including destructive effect, I am directed to observe that as the instructions of the Secretary of State require a full report on Mr. Whitworth's system of breech-loading Field Artillery, all these points will be included in that inquiry; and as the standard of comparison must necessarily be the corresponding breech-loading gun of the service, the Committee hope that every particular you require will be brought into view.

"I have the honour to be, Sir,
"Your obedient Servant,
"J. H. LEFROY, Col. R.A.,
"*Secretary to the Ordnance Select Committee.*"

V.—Report of Ordnance Select Committee on the Range and Deflection of Whitworth and Armstrong Guns.

Armstrong's Breech-loading 12 pr. Gun *versus* Whitworth's Breech-loading 12 pr. Gun.

Object.—To ascertain Range and Deflection of Whitworth's Breech-loading 12 pr. Gun in comparison with Armstrong's Gun.

Date.	No. of Rounds.	Charge.	Elevation.	Armstrong's 12 pr. B. L. No. 6. cwt. qrs. lbs. Weight . . . . 8 2 11 Length . . . . 7 feet.							Whitworth's 12 pr. B. L. No. 1. cwt. qrs. lbs. Weight . . . . . 9 3 0 Length . . . . . 8 feet 8 inches.							Armstrong.		Whitworth.	
				Range.			Mean diff. of Range.	Deflection.		Mean Time of Flight.	Range.			Mean diff. of Range.	Deflection.		Mean Time of Flight.	Rectangle.	Area expressing Error.	Rectangle.	Area expressing Error.
				Min.	Max.	Mean.		As observed.	As referred to Mean Direction.		Min.	Max.	Mean.		As observed.	As referred to Mean Direction.					
1861		lbs.	degs.	yds.	yds.	yds.	yds.	yds.	yds.	sec.	yds.	yds.	yds.	yds.	yds.	yds.	sec.	yds.	yds.	yds.	yds.
2nd April	5	1·50	2	1108	1150	1130	12	4·2	1·04	3·42	1159	1223	1198	19	1·38	0·75	3·50	40·88× 2·74	110	64·61×1·98	128
”	”	1·75	”	1226	1307	1256	26	5·2	1·48	3·62	1250	1344	1290	28	1·50	1·08	3·46	86·24× 2·98	257	104·70×2·85	298
”	”	1·50	5	2128	2165	2146	11	9·2	1·48	6·78	2072	2486	2368	119	1·40	1·72	6·96	36·92× 3·90	144	388·97×4·54	1766
”	”	1·75	”	2331	2399	2360	18	11·6	0·80	7·28	2335	2644	2471	97	1·79	0·64	7·06	59·86× 2·11	126	313·81×1·69	530
”	”	1·50	10	3512	3597	3568	24	12·6	2·14	12·30	4137	4318	4223	68	3·00	0·85	12·62	80·97× 5·64	457	226·80×2·24	508
”	”	1·75	”	3866	3961	3908	35	17·0	6·17	12·92	4348	4449	4400	25	6·90	2·92	13·08	118·25×16·27	1875	84·39×7·70	650

Summary.

The general average of range is as 2658 to 2394 in favour of the Whitworth Gun.
The general average of accuracy is as 647 to 495 in favour of the Armstrong Gun.
The Whitworth 12 pr. is heavier than the Armstrong 12 pr., in the proportion of 1092 to 963, and 20 inches longer

(Signed) J. H. Lefroy.

VI.—Report of Experimental Practice.—Armstrong Gun.—Shoeburyness, April 2, 1861.

ARMSTRONG BREECH-LOADING 12 PR.

No. 1. REPORT OF EXPERIMENTAL PRACTICE.

Shoeburyness, 2nd April, 1861.

Height of axis of Gun above plane, 3½ feet.

Ordnance . . Nature, Armstrong's B. L. 12 pr. Gun, No. 6.
Weight . . . . . 8 cwt. 2 qrs. 11 lbs.
Length . . . . . 7½ feet.
Diameter of Bore . . 3 inches.
Spiral, if rifled, 1 turn in 38 calibres.
Grooves, Number 38. Width, 0·15 inches. Depth, 0·05 inches.

Barometer, 29·7.
Wind, South—3.
Direction of Wind

Nature and object of the Experiment—To ascertain the Range, &c., of Armstrong's Breech-loading 12 Pr. Iron Gun, in comparison with Whitworth's Breech-loading 12 Pr.

Programme received, 28th March. Stores received, 2nd April, 1861. Minute No. 3625.

No. of Round.	Charge.	Elevation.	Recoil.	Projectile.			Times and Mean Time of Flight.	Range, 1st graze.	Mean Range, 1st graze.	Deflection.			Remarks.
				Nature.	Weight and Mean Weight.	Windage in Inches.				Correction allowed for.	Left.	Right.	
	lbs.	deg.	Feet.		lbs. mean.		seconds	yds.	yds.		yds.	yds.	
1	1·75	2	8·0	Armstrong's Solid Shot.	12	Nil.	3·5	1239	–	Nil.	4⅔	–	3rd April.
2	–	–	7·10		–	–	3·7	1271	–	–	6⅔	–	
3	–	–	8 0		–	–	3·6	1238	–	–	6	–	
4	–	–	8·0		–	–	3·7	1307	–	–	4	–	
5	–	–	8·0		–	–	3·6	1226	1256	–	4⅔	–	
6	1·5	–	7·0		–	–	3·4	1108	–	–	5⅓	–	
7	–	–	7·0		–	–	3·4	1133	–	–	5	–	
8	–	–	7·0		–	–	3·6	1150	–	–	4⅓	–	
9	–	–	7·0		–	–	3·4	1121	–	–	3	–	
10	–	–	7·0		–	–	3·3	1137	1130	–	3⅓	–	
11	1·5	5	6·9		–	–	6·8	2134	–	–	11	–	2nd April.
12	–	–	6·8		–	–	6·9	2165	–	–	9	–	
13	–	–	6·6		–	–	6·6	2157	–	–	8⅔	–	
14	–	–	6·6		–	–	6·8	2146	–	–	10⅓	–	
15	–	–	6·6		–	–	6·8	2128	2146	–	7	–	
16	1·75	–	7·9		–	–	7·2	2357	–	–	13	–	Wind increased to 4.
17	–	–	8·0		–	–	7·3	2331	–	–	11⅓	–	
18	–	–	7·10		–	–	7·2	2356	–	–	11	–	
19	–	–	8·0		–	–	7·4	2351	–	–	11⅔	–	
20	–	–	8·0		–	–	7·3	2399	2360	–	11	–	
21	1·5	10	4·6		12	–	12·2	3512	–	–	12	–	Wind changed and increased. Squally.
22	–	–	4·8		–	–	12·4	3576	–	–	11	–	
23	–	–	4·6		–	–	–	3593	–	–	17	–	
24	–	–	4·6		–	–	12·4	3597	–	–	12	–	Wind increased to 6, and continued squally.
25	–	–	4·5		–	–	12·2	3563	3568	–	11	–	
26	1·75	–	5·0		–	–	12·8	3943	–	–	8	–	
27	–	–	5·0		–	–	12·8	3898	–	–	23	–	
28	–	–	5·0		–	–	13·0	3961	–	–	14	–	
29	–	–	5·1		–	–	13·0	3866	–	–	19	–	
30	–	–	5·1		–	–	13·0	3873	3908	–	21	–	

Elevation throughout by Quadrant.

The Gun was mounted on a Travelling Carriage, and placed on one of Lieut.-Colonel Clerk's Platforms, on the level.

Wads, choked in the Cartridge, were used throughout the Practice.

The Secretary,
Ordnance Select Committee.

(Signed) A. J. Taylor, Colonel R.A.,
Commandant and Superintendent.

VII.—Report of Experimental Practice.—Whitworth Gun.—Shoeburyness, April 2, 1861.

WHITWORTH BREECH-LOADING 12 PR.

No. 1. REPORT OF EXPERIMENTAL PRACTICE.

Shoeburyness, 2nd April, 1861.

Height of axis of Gun above plane, 3½ feet.

Ordnance . . { Nature, Whitworth's B. L. 12 Pr. Gun, No. 1.
Weight . . . . . . 9 cwt. 3 qrs. 0 lbs.
Length . . . . . . 8$\frac{8}{12}$ feet.
Diameter of Bore. Major axis 3 in., Minor 2·75 in.
Spiral, if Rifled, 1 turn in 55 inches.
Grooves, Number . Width, . Depth, .

Barometer, 29·7.
Wind, South—3.
Direction of Wind }

Nature and object of the Experiment—To ascertain the range, &c., of Whitworth's Breech-loading 12 Pr. Iron Gun, in comparison with Armstrong's Breech-loading 12 Pr.

Programme received, 28th March. Stores received, 2nd April. Minute No. 3625.

No. of Rounds.	Charge.	Elevation.	Recoil.	Projectile.			Times and Mean Time of Flight.	Range, 1st graze.	Mean Range, 1st graze.	Deflection.			Remarks.
				Nature.	Weight and Mean Weight.	Windage in inches.				Correction allowed for.	Left.	Right.	
	lbs.	deg.	Feet.		lbs. mean.		seconds	yds.	yds.		yds.	yds.	
1	1·75	2	7·0	Solid Shot—Hexagonal shaped.	12·094	–	3·5	1266	–	Nil.	⅓	–	3rd April.
2	–	–	7·3		–	–	3·6	1344	–	–	–	3	
3	–	–	7·6		–	–	3·4	1250	–	–	–	2	
4	–	–	7·3		–	–	3·4	1280	–	–	–	1	
5	–	–	7·6		–	–	3·4	1306	1290	–	–	1⅓	
6	1·5	–	6·6		–	–	3·6	1223	–	–	–	2⅓	
7	–	–	6·6		–	–	3·6	1211	–	–	–	1⅓	
8	–	–	6·6		–	–	3·4	1188	–	–	–	2	
9	–	–	6·6		–	–	3·5	1209	–	–	0	0	
10	–	–	6·6		–	–	3·4	1159	1198	–	–	1⅓	
*11	1·5	5	6·0		–	–	7·2	2442	–	–	1⅔	–	2nd April.
12	–	–	6·0		–	–	6·2	2072	–	–	–	2	
13	–	–	6·0		–	–	6·8	2389	–	–	–	⅓	
14	–	–	5·10		–	–	7·2	2449	–	–	–	2	
15	–	–	6·0		–	–	7·2	2486	2368	–	1	–	
16	1·75	–	7·0		–	–	7·0	2475	–	–	2⅓	–	Wind increased to 4.
17	–	–	7·0		–	–	7·2	2644	–	–	1	–	
18	–	–	6·9		–	–	6·9	2335	–	–	2	–	
19	–	–	7·0		–	–	7·0	2370	–	–	1⅓	–	
20	–	–	7·0		–	–	7·2	2533	2471	–	2⅓	–	
*21	1·75	10	6·9		–	–	13·2	4409	–	–	4	–	Wind changed and increased. Squally.
22	–	–	6·8		–	–	13·0	4348	–	–	10	–	
23	–	–	6·8		–	–	12·8	4387	–	–	7⅔	–	
24	–	–	6·9		–	–	13·0	4405	–	–	8⅔	–	Wind increased to 6, and continued squally.
25	–	–	6·9		–	–	13·4	4449	4400	–	4	–	
26	1·5	–	5·0		–	–	12·6	4137	–	–	4	–	
27	–	–	5·6		–	–	12·9	4299	–	–	3	–	
28	–	–	5·0		–	–	1·0	4139	–	–	2⅓	–	
29	–	–	5·0		–	–	12·8	4318	–	–	3⅔	–	
30	–	–	5·0		–	–	12·8	4220	4223	–	2	–	

Elevation throughout by Quadrant.

The Gun was mounted on a Travelling Carriage, and placed on one of Lieut.-Colonel Clerk's Platforms, on the level.

The Powder and Wad were contained in the usual Tin Cases.

The rounds marked * were fired with Tin Cases that had been used previously, there being no more in store, and they were simply well cleaned and answered quite as well as when new.

The Wad weighs about 2 oz. 4 drs., and the empty Tin Case about 8 oz. 8 drs.

The Secretary,
Ordnance Select Committee.

(Signed) A. J. Taylor, Colonel R.A.,
Commandant and Superintendent.

VIII.—**Memorandum** as to the mode adopted by the Ordnance Select Committee, at the instance of Captain Noble, R.A., of calculating Rectangles, exhibiting comparative error in different Guns.

"In estimating the relative degrees of accuracy of guns of different descriptions, two natures of error have to be taken into consideration, viz., errors in range, and errors in deflection. It not unfrequently happens that a gun may have very considerable accuracy in one of these particulars, while in the other the errors may be very large. It has been found therefore desirable in instituting comparisons, whether between different guns at the same range, or between the same gun at different ranges, to have a ready means of representing graphically the degree of accuracy which has been attained.

"It is usual to denote the degree of certainty which has been attained in the result of a series of observations, by attaching to this result the probable error with which it is affected—that is to say, that error, than which there are as many errors less as there are errors greater; or, in other words, that error regarding which it is an equal chance whether or not it be exceeded.

"The errors in artillery practice being in two dimensions, the degree of accuracy attained by any gun was in a similar manner measured by combining the errors, within both of which concurrently it was an even chance that the errors of a given round should fall.

"The first points to be determined are the probable errors in range and deflection. To obtain the probable error in range, the mean of the observed ranges must be taken; and, assuming the mean range to be the true one, the errors must be determined by subtracting the mean from the observed ranges, or *vice versâ*. Then adding all these errors, without regard to sign, the mean error will be found from

$$\epsilon_{,} = \frac{\text{num. of errors}}{m-1} \quad . \; . \; . \; . \; . \; . \; . \quad (1),$$

where m = number of rounds fired.

"The probable error in range is then given by the Equation

$$h = \cdot 8453\,\epsilon_{,} \quad . \; . \; . \; . \; . \; . \; . \; . \quad (2).$$

Now with regard to deflection, it is to be observed that the errors must not be reckoned from the line of fire, but the mean point of deflection must be determined, and the errors, right or left, computed from this point.

"Then, as in the case of the range, the mean error will be given by Equation (1), the probable error by Equation (2).

"We have now obtained the probable error of a single shot both in range and deflection; but it will be observed, that since the probability of each event is $\frac{1}{2}$, the probability of a shot falling within both probable errors is $\frac{1}{4}$; and we have still to determine the limits in range and deflection which shall be such, that it will be an equal chance that the errors of a single round will fall within both.

"Now these limits we can determine in the following way. The probability of the occurrence of an error between Δ and 0 (Δ being taken without regard to sign) is given by the value of the definite integral

$$\frac{2h}{\sqrt{\pi}} \int_0^{\Delta} e^{-h^2\Delta^2}\, d\Delta \quad . \; . \; . \; . \quad (3),$$

where h is a constant, whose value is deduced from the observations under discussion.

"Let us now suppose that we have found an error in range Δ', within which about $\frac{7}{10}$ths of the errors ($\cdot 7071$) will probably fall, and an error Δ'' in deflection, within which we may also expect the same number of errors to fall; then the probability of a shot falling, so that its error in range shall be less than Δ', and that in deflection less than Δ'' will be $\frac{1}{2}$.

"The definite integral (3) enables us to find Δ' in terms of ϵ. This integral has been tabulated according to an argument in which the probable error is assumed to be unity. For the argument $\frac{\Delta}{r}$ the table gives the value of

$$\frac{2}{\sqrt{\pi}} \int_0^{\rho\frac{\Delta}{r}} e^{-t^2}\, dt \quad . \; . \; . \; . \; . \; . \quad (4).$$

(where $t = h\,\Delta$),

that is, it shows how many errors may be expected to be less than a given error, provided the ratio of the given error to the probable error be known.

"Conversely, the value of (4), or the number of errors which should fall within a certain unknown limit Δ, being known, the table will give the proportion which Δ bears to the probable error.

"In the case before us we have

$$\frac{2}{\sqrt{\pi}} \int_0^{\rho\frac{\Delta}{r}} e^{-t^2}\, dt = \cdot 7071$$

whence we have

$$\frac{\Delta}{r} = 1\cdot 56$$

$$\therefore\ \Delta = 1\cdot 56\, r$$

"Hence, in order to find the errors in range and deflection, within both of which it is an even chance that a given shot will fall, it is necessary to multiply the probable errors as already determined by 1·56.

"For the sake of clearness, it may be as well to recapitulate the various steps to be taken.

"1st. As regards range. Find the mean range, and thence the error of each round.

"The mean error is then given by the Equation

$$\epsilon_{,} = \frac{\Sigma\,(\Delta)}{m-1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (A),$$

where $\Sigma\ (\Delta)$ = sum of the errors without regard to sign, and m = number of rounds fired.

"The probable error is then given by the Equation

$$r = \cdot 8453\, \epsilon_{,} \quad . \quad . \quad . \quad . \quad . \quad . \quad (B).$$

"2nd. As regards deflection. Find the mean point of impact, and thence the error in deflection of each round. Compute the mean error $\epsilon_{,}'$ and the probable error r', from Equations (A) and (B) respectively.

"Lastly, to obtain the errors (R and R′) in range and deflection, within both of which it is an even chance that the errors of any given round will fall, multiply the probable errors as obtained by Equation (B) by 1·56.

"To obtain a graphical representation of the above results, if we lay down to scale a rectangle whose sides are 2 R and 2 R′, the centre of the rectangle being the mean point of impact, the area will be such that it will be a measure of the accuracy of the gun in question, and it will be an even chance whether a given shot fall within or without it.

"As an illustration of this method may be selected the experiments made by the Committee on rifled cannon to determine the accuracy of Sir William Armstrong's 18-pounder. As regards range, the practice gave the following data in yards:—

1023	1018	1005	1020	1005	1005	1018	1005	1026	1014
1032	1020	1025	1024	1023	1038	1032	1032	1026	1007
1002	1002	1002	1005	1018	1013	1032	1024	1005	1004
1018	1018	1025	1012	1037	1038	1032	1026	1018	1025

and these results give a mean range of 1019 yards.

"Hence the errors, assuming the mean range to be the true one, are, when arranged according to magnitude, and without regard to sign,

19	17	14	14	13	7	6	5	1	1
19	17	14	13	13	7	6	5	1	1
18	15	14	13	12	7	6	4	1	1
17	14	14	13	7	6	5	4	1	1

and the mean error by Equation A is

$$\epsilon_{,} = \frac{366}{39} = 9\cdot 38 \text{ yards},$$

and by Equation (B)

$$r = 7\cdot 9 \text{ yards}.$$

"Again, the deflections corresponding to the above ranges were, in inches—

32 right	2 left	6 right	30 right
30 "	20 right	4 left	42 "
24 "	38 "	0 "	48 "
19 "	39 "	15 right	16 "
33 "	39 "	15 "	20 "
33 "	39 "	15 "	24 "
25 "	32 "	8 "	16 "
2 left	32 "	37 "	6 left
2 right	18 "	28 "	4 "
3 "	14 "	28 "	17 right

"Hence the mean point of impact is 20 inches right; and the errors arranged according to magnitude, and without regard to sign, are—

28	22	19	18	13	12	8	5	4	2
26	22	19	17	13	12	8	5	4	1
24	22	19	17	12	10	6	5	4	0
24	20	18	14	12	10	5	4	3	0

"Hence from (A) the mean error is 12·4 inches; and from (B) the probable error is 10·4 inches.

"And the rectangle to which we have alluded will be 24·5 yards long by 31·5 inches broad, and within this area half of the rounds fired may be expected to fall.

"In the original comparison the mean error was determined from the sum of the squares of the errors; but this method is very laborious, and for artillery practice is not necessary.

"For further details on the subject, the communication in the 'Occasional Papers of the Royal Artillery Institution, Woolwich,' Vol. I. (pp. 173 to 189), must be referred to."

IX.—Extract from the "Report of the Commissioners appointed to consider the Defences of the United Kingdom;" p. lvi.

171. Your Commissioners now proceed to submit a concise statement, in tabular form, of the number of guns, amount of barrack accommodation, and probable expense of all the works they have recommended, together with similar information respecting those in progress.

Station.	Guns.		Barrack Accommodation, chiefly Bomb-proof.		Expense of Works, including Purchase of Land.	
	No.	Total No.	No. of Men.	Total No.	—	Total.
Portsmouth and Isle of Wight.					£.	£.
Recommended by Royal Commission	987		7,320		2,400,000	
In works in progress	280	1,267	1,500	8,820	400,000	2,800,000
Plymouth.						
Recommended by Royal Commission	742		7,010		2,670,000	
In works in progress	120	862	1,000	8,010	350,000	3,020,000
Pembroke.						
Recommended by Royal Commission	163		1,700		600,000	
In works in progress	150	313	1,000	2,700	165,000	765,000
Portland.						
Recommended by Royal Commission					*250,000	
In works in progress	300	300	2,300	2,300	380,000	630,000
Thames.						
Recommended by Royal Commission	110	110	1,100	1,100	180,000	180,000
Medway and Sheerness.						
Recommended by Royal Commission	204	204	1,400	1,400	450,000	450,000
Chatham.						
Recommended by Royal Commission	335	335	3,550	3,550	1,350,000	1,350,000
Woolwich.						
Recommended by Royal Commission	150	150	1,500	1,500	700,000	700,000
Dover.						
Recommended by Royal Commission	30		300		170,000	
In works in progress	60	90	300	600	165,000	335,000
Cork.						
Recommended by Royal Commission	90	90	600	600	120,000	120,000
Total Guns and Barracks . .	3,721		30,580			
Armaments of Works recommended by Royal Commission						500,000
Floating Defences						1,000,000
Total Estimate of Expense . . . . £						11,850,000

* £100,000 for purchase of land, and £150,000 for works already projected.

X. EXTRACT from "Evidence taken before the Commissioners appointed to consider the Defences of the United Kingdom;" pp. 24 to 28.

"Friday, 4th November, 1859.

PRESENT:

Major-Gen. Sir HARRY D. JONES, K.C.B.	Captain ASTLEY COOPER KEY, R.N., C.B.
Major-General CAMERON, C.B.	Colonel LEFROY, R.A.
Rear-Admiral ELLIOT.	JAMES FERGUSSON, Esquire.
Maj.-Gen. Sir FREDERICK ABBOTT, C.B.	

Major JERVOIS, R.E., *Secretary.*

Major-General Sir HARRY D. JONES, K.C.B., in the Chair.

Captain COWPER PHIPPS COLES, R.N., examined.

359. (*Chairman.*) I believe you were Flag Lieutenant to Admiral Lyons at the attack on Sebastopol on board the 'Agamemnon?'—Yes.

360. Will you have the goodness to tell us whether you felt much inconvenience from smoke hanging over the ship after you opened fire?—Very great.

361. Do you think that the same effect took place with Fort Constantine?—More so.

362. The 'Agamemnon' was struck by shot from the enemy several times, was she not?—Yes; she was hit 214 times.

363. Do you suppose that those shot were principally fired from Fort Constantine, or from any other batteries; could you tell at all by the direction in which the shot came into the vessel?—Principally from Fort Constantine, but I should say at least one-third from Wasp Fort and the line of earthen batteries in that vicinity and the hills; also from the southern Fort Alexander, which fired across at us, being 1,800 yards from us.

364. How far were you from Fort Constantine?—770 yards.

365. Have you any idea what distance the Wasp was from you?—I think the Wasp was more; Wasp Fort was 1,200 yards.

366. Your vessel, I suppose, was moored more directly to throw her fire against Fort Constantine, or did you bring up in the best way you could?—If you will allow me, I will describe to you the way that we went in. We proceeded in at very slow speed, passing by the forts in the vicinity of Wasp Fort at very slow speed, merely firing one or two guns from the bow, and we did not open our broadside until we had been twenty minutes under the fire of the Russians; we then opened our broadside on Fort Constantine, shortly after which an explosion took place in Fort Constantine.

367. (*Captain Key.*) Did you anchor before you opened your broadside?—We did.

368. (*Chairman.*) You came down parallel to the coast?—We did nearly, and as we passed Wasp Fort we just fired one bow gun, and so on; we then opened our broadside, and were obliged to stop frequently for the smoke to clear away to see the fort. I remember being sent down repeatedly by Admiral Lyons, to tell them to cease firing on the deck until the smoke had cleared away sufficiently to take aim.

369. (*Captain Key.*) What sort of wind had you?—We had a light wind off shore, which I imagine caused the smoke to hang under Fort Constantine. After we had been in action an hour and a half, several of the other vessels were obliged to move out, leaving the 'Agamemnon' and 'Sanspareil,' which was close astern of us, within half a ship's length, when all the forts, Wasp Fort and the earthen batteries on the cliff, and also Fort Alexander, turned their fire upon us. The French ships being at a great distance, their broadsides fell short, striking the water across our bows; they were supposed to be engaging Fort Alexander. We then found that the guns from Wasp Fort and the earthen batteries on the cliff were doing us more harm than those from Fort Constantine, and we were obliged to divide our fire, telling some of the after quarters to fire on Wasp Fort and the foremost quarters to fire on Fort Constantine.

370. Did your fire check the fire of Wasp Fort after that?—No; I do not think that it did. I do not think that it did much harm to Wasp Fort. There was an earthen glacis round it, and it must have been a very good shot to have touched such a small object.

371. (*Colonel Lefroy.*) What elevation had you to give for Wasp Fort?—That I do not remember.

372. As much as ten degrees?—No.

373. (*Major-General Cameron.*) Did Fort Constantine ever cease its fire?—Fort Constantine slackened its fire very much.

374. But it did not cease altogether, as you mention was the case in the 'Agamemnon,' on account of the smoke?—No. They may have ceased for a few minutes, but we could not tell that, for, from the quantity of smoke, we could not see, and from the buzz of shot, shell, and missiles of all descriptions that were flying about us we could not tell which was firing and which was not.

375. (*Chairman.*) After the smoke had cleared away did it appear to you from the ship that you had done much damage to Fort Constantine, as far as you could see with your glasses?—The guns on Barbette appeared to have been all either silenced or deserted.

376. During the action could you see the Wasp Battery pretty distinctly?—Now and then you could.

377. The smoke did not appear to hang so much over it as over Fort Constantine?—No. We could see the Wasp Battery.

378. All the time?—When the smoke cleared away; but the 'Sanspareil' was just on our quarter, and after she had been firing for some time we could not see it occasionally.

379. The operations of that day never contemplated your going in to force the boom?—No, I believe not. I believe that ours was only supposed to be a feint to draw their attention off other points; but that is only from hearsay; I never saw anything official.

380. Your ship, I suppose, was perfectly steady; there was no sea running?—It was perfectly smooth water.

381. Do you recollect at all whether the ship after you had been in action a short time gained any motion?—To a certain degree the same as at general quarters: to prevent which, I know, as an old first lieutenant, is one of our dodges, that if you are being inspected, and you wish to make good practice at a target, the thing is to keep the men as quiet as possible, because the least movement will cause the ship to roll.

382. Was it the opinion aboard the fleet at that time that if it had been ordered they could have forced the booms?—I think that was said by a great many, but it was very doubtful whether we could have forced the sunken ships. If it had been the boom alone, I think we could have forced it without any difficulty, but the sunken ships were the difficulty.

383. (*Captain Key.*) What sort of boom was it; chain and timber?—Yes; two rows of chains were passed along the spars, and the chains were lashed to the spars by smaller chains, as you lash a hammock up. A Pole showed me a model of it.

384. (*Chairman.*) Who has the model of it now?—It was made with a bit of string. I could show you exactly what it was.

385. Were you in the batteries on shore at any time when they were engaged?—No, I never was, excepting looking on whilst they were firing, but never during any of the attacks.

386. Have you been engaged at any other places against land batteries?—I was, at Kinburn, Kertch, Arabut, Genitschi, Taganrog, and up the Dnieper.

387. (*Major-General Cameron.*) Did any shells burst on the deck?—No, not on our decks; but several on board the 'Sanspareil' at Sebastopol; and that was why their loss was more severe, I think, than ours; they had 9 men killed, and, I think, 20 wounded, and we had only 4 men killed and 24 wounded.

388. (*Captain Key.*) Had you no shell which burst on board you at all from striking your side?—Yes. We had one which burst, I now remember, on the main deck, and two in the bunt of the main yard, which set fire to the mainsail.

389. (*Chairman.*) Was the 'Agamemnon' the ship which was struck by a rocket?—She was.

390. (*Captain Key.*) Under water?—Under water.

391. (*Chairman.*) At what depth below the water line?—It was 6 feet, I think.

392. Were rockets very generally used against ships?—On that day they fired a great many rockets.

393. And that appears to have been the only one which was effectual?—That was the only one which was effectual with us. I have stated that no shell burst on board us, but a great number of shells burst over us in the rigging. The only reason why I can fancy that we were allowed to remain there as we did for four hours is that they fired too high; we had hardly a rope in the ship that was not cut, and the upper deck was completely covered with splinters; but having no men on our upper deck quarters in a great measure accounts for our small loss. The marines were on shore, so that luckily we did not man the upper deck guns.

394. Did the explosion of the rocket produce a great effect upon the ship from the concussion?—The chaplain and surgeon were in the boatswain's storeroom, amputating a man's leg; the chaplain was sitting in a chair close to the part where the rocket came in, and it nearly threw him out of his chair. He told the story afterwards, and said that he thought that a shell must have come into the ship there, the concussion was so great. Upon sending down a diver to look at the ship's bottom, the end of this rocket was found sticking in. I think it was a 6-lbs. rocket, if I remember rightly, but it had gone in and exploded, giving this shock.

395. Did you see any of the French rockets fired during the siege?—No, I did not notice any; the fact was that the smoke was so great that we could see very little of the French ships.

396. (*Sir Frederick Abbott.*) Were you struck by red-hot shot?—No; at least no red-hot shot lodged. Several shot coming at an angle scooped out pieces of the side; they might have been red-hot, but we did not detect any which were so.

397. (*Chairman.*) Have you any idea what was the nature of the guns which they fired at you?—The Russian 32-pounders, which I think are a trifle larger than ours.

398. (*Sir Frederick Abbott.*) Were those the largest?—Those at Wasp Fort, I imagine, were 68-pounders.

399. Could the forts at Sebastopol have stopped your fleet from going through if there had been no obstructions? [*The Chairman here explained that the question was, whether the forts could have stopped the ships, not considering what would have taken place when inside.*]—Certainly not.

400. (*Captain Key.*) You have stated that you could have forced the boom?—Yes; if the sunken ships had not been there.

401. Was not there a passage through the sunken ships?—Yes.

402. Then if you had forced the boom could not you have taken that passage?—The sunken ships were outside the boom. We did not know the passage; it was a winding passage, therefore we should have lost our speed.

403. Do you know of any instance of a ship being struck by red-hot shot during the action?—Yes. At Odessa a French steamer (the 'Vauban,' I think), was struck by a red-hot shot, which lodged in her side. She came out of action, and the signal was made for boats to go to her assistance, which they did; she was on fire from it.

404. Seriously on fire?—That I do not remember; but I imagine she was. We never heard the exact account of it.

405. You say that your guns were very much obscured by smoke, and that there was a light wind off shore. Was it more the smoke of Fort Constantine or the smoke of your own guns?—Both; but more the smoke of our own guns.

406. What strength would you call the wind: number what?—No. 2, I think, when we commenced; but as is always the case with much firing it became nearly a calm, and caused the smoke to hang about the ships and forts.

407. Some of the ships were struck by shell at Sebastopol, were they not?—Yes; the 'Albion' and the 'Arethusa,' and several others.

408. Have you any idea of the number of shells which burst in the 'Albion?'—I cannot remember, but several.

409. (*Sir Frederick Abbott.*) Have you ever seen an 8-inch or a 10-inch shell explode between decks of any ship?—No; but I remember, when off Alexandria, during the Syrian war, the 'Medea' was to windward of the fleet, and hoisted the signal in want of assistance, on which the signal was made for all the boats of the squadron to proceed to her assistance. I was midshipman of one of the 'Ganges' boats, and we as a matter of course raced to the ship. When we got to

her we found several wounded men lying upon deck, and the ship in great confusion, from a shell having exploded in the cockpit while a marine artilleryman was doing something to the fuse.

410. What was the size of the shell?—It was either a 10-inch or an 8-inch shell, because her two shell guns were of that calibre.

411. (*Chairman.*) That was a shell which burst on board, and was not thrown on board?—It burst on board; the whole of her bulk heads were shivered and knocked down; her light work.

412. (*Captain Key.*) Did you hear of the amount of smoke emitted?—It was said to be very great, but I cannot exactly say how much; I did not see it.

413. It was in the gun-room, I think?—In the gun-room or the cockpit; I am not quite sure which; it was between decks.

414. (*Chairman.*) Were there land batteries erected against the fort at Kinburn, or was it destroyed entirely by the fire from the ships?—Entirely by the fire from the ships.

415. You were in the fort afterwards?—Yes.

416. Did you consider it a respectable fortification?—The sea face was strong.

417. Could a heavy fire be brought upon the ships from the position which they took up?—No; with the exception of the floating batteries, they were too far off, in consequence of the shallowness of the water. I do not exactly remember the distance, and the floating batteries being the nearer, the fort directed its fire upon them, and very few of the ships were struck.

418. Were any shells from mortars thrown at the ships?—I think not. I since remember that there were.

419. Was not there a large garrison with nearly 2,000 men in it?—Yes.

420. Then you may consider it as a fortification of considerable size which was entirely taken by fire from ships?—Entirely, and by an overwhelming fire, because we surrounded it.

421. (*Captain Key.*) Was it a single work?—No; there were three works; two on the point, besides Fort Kinburn; those on the point were earthworks.

422. (*Chairman.*) Do you remember how long you were firing at it before it surrendered?—If I remember rightly, it was about two hours.

423. It was considerably damaged, and the guns were knocked about, were they not?—Very much indeed, particularly the angle facing the floating batteries.

424. (*Major-General Cameron.*) Could they have held out longer, or did they surrender because they saw that resistance was hopeless?—The fort being open in the centre, and our ships being on both sides of it, there was a tremendous cross fire, so that if a shot missed one parapet it lodged in the rear of the opposite one.

425. (*Captain Key.*) About what diameter across was it: 100 yards?—More than that; I think it was 200 yards at least.

426. Was this fort of which you are speaking an earthen work?—The main fort was a regular fort built of stone, brick, and earth; then on the spit there were two other forts, which they had built up of timber lining and earth outside. with embrasures which flanked the entrance.

427. (*Major-General Cameron.*) Was the fire of the fort completely silenced before it gave in?—Completely.

428. (*Sir Frederick Abbott.*) Did you silence any of these earthen batteries?—I do not think that they were silenced, but several of their guns were dismounted.

429. (*Chairman.*) Had you been on board or seen the French iron-plated vessel before she went into action?—I saw her after she had been in action.

430. Do you know what was the opinion amongst the French naval officers as to the resistance which these plates would offer to shot; whether they felt themselves quite secure against heavy shots?—A French officer of the floating battery appeared to consider them quite secure against the guns used at Fort Kinburn; no plates were broken; they were merely indented; but two or three men were killed or wounded by shot entering the port.

431. At what distance was she from the batteries?—600 or 700 yards.

432. Did she appear to take up a more advanced position than the others, from

the circumstance of her being so protected?—From the circumstance not only of her being so protected but of her light draught of water.

433. (*Major-General Cameron.*) There was only one floating battery iron-plated was there?—There were three.

434. I suppose the fort would have been taken without the aid of that floating battery?—Certainly, from the cross fire; if we missed the parapet the shot went into the fort, lodging in the opposite side. I think that they held out wonderfully well; they had not the least chance.

435. (*Captain Key.*) Were there guns in embrasures?—Yes.

436. (*Mr. Fergusson.*) Was not the masonry of the fort very much exposed?—Quite exposed.

437. (*Chairman.*) There was no glacis at all?—No glacis.

438. (*Captain Key.*) Was the fort breached at all?—No; it was not breached; they had evidently fired at the guns; they had not wished to breach it.

439. (*Sir Frederick Abbott.*) You have stated that the fire from the Wasp Fort was more destructive or annoying than that from any other fort; will you explain why?—I fancy that they could see better through the smoke, from having no embrasures (I would here wish to remark, that embrasures, in casemated forts, when once filled with smoke, obscure the sight), and being high up they were less molested by the fire of the ships, to a certain extent; but I also imagine that they had superior gunners in Wasp Fort, for it was hardly ever known to make a bad shot. On one occasion, when reconnoitring in the 'Fury,' with the French and English generals on board, at daylight, or rather as the day broke, we stopped, as we thought, off Wasp Fort, out of range, and they suddenly opened fire.

440. (*Captain Key.*) At what distance?—We did not know. I think we supposed afterwards that we were about 2,000 yards off. The first shot struck the water within a few feet, and went into the midshipmen's berth; the second shot, in quick succession, dropped under our stern; and the third passed between the mainmast and the mizenmast, and we thought it advisable to move on.

441. (*Sir Frederick Abbott.*) Then the advantage was not at all connected with the direction of the shot, that is to say, its coming down from a greater height upon your decks?—No; the angle would be so little that I do not think that it made any great difference; but it was also in a raking position, as Wasp Fort was on our quarter. I would mention, if it is not trespassing, with regard to ships passing forts, that at Kinburn our gun-boats and the French gun-boats ran through the channel close to the forts at night without being struck, or at all events no casualties occurred, and one of our gun-boats, the 'Cracker,' I think, the next day, in broad daylight, came through the passage, the whole of the forts firing at her.

442. (*Captain Key.*) At what distance?—Within 200 yards. I forget the exact distance. The passage runs close to the fort. She did so without being struck, and returned.

443. They firing at her?—Yes.

444. (*Chairman.*) I suppose that if you were passing two forts in a good broad channel, and their guns were presumed to be laid for the middle of the channel, if you stuck well in on one side you would pretty well escape being struck?—That would depend upon circumstances. If the guns in the fort were higher than the ship, and you passed close to the fort, they certainly would miss you; you would pass under their fire. I would here wish to add, particularly when you have a rise and fall of 16 feet tide, at low water all this masonry would be exposed and your guns high above the water. If they were low the lower guns would hull you. In a three-tier battery, for instance, the upper guns I fancy would not.

445. Did you ever hear any remarks made by the Russians in Fort Constantine about the smoke during action—whether they had felt any inconvenience from it?—No.

446. Had you an opportunity of seeing what had been the effect of your fire upon Fort Constantine after the peace?—I only saw it through a glass; before we got possession of the north side I left. The fort, on looking at it some days after, appeared much marked, and the embrasures a good deal knocked about; it had shores of timber placed against it, apparently to prop it up.

447. (*Captain Key.*) From your experience of the forts at Sebastopol, if you had to place guns to command the entrance of a harbour, for its protection, at what height would you place them, if you could choose your height; would you have them on the water's edge, or 200 feet high, or 100 feet high, or 150, or 80?—Against wooden ships I would place them at different heights and different distances from the entrance to be disputed.

448. (*Major-General Cameron.*) In order to distract the fire of the ships?—Yes.

449. (*Captain Key.*) Against iron ships what would you do?—That would be quite a different thing.

450. (*Chairman.*) Do you think that if the Wasp Battery had been higher or lower, its fire would have been more effective?—If lower they could have laid their guns with more precision; they could have taken better shots; but being high enabled them to have a better view of the ships over the smoke.

451. (*Captain Key.*) Do not you think that they would have much less chance of being hit if they were high?—Much less chance.

452. Against iron ships where would you put the guns?—If I wished to dispute a passage against iron ships, I would place the guns as close together and as near to the ships as possible, so as to be able to throw a simultaneous broadside on one portion of the ship.

453. What number of guns were there in the Wasp Fort?—I think 12; I am not quite certain that I am right; that number was taken merely from looking through a glass.

454. What number were in Fort Constantine?—104, but they did not all bear upon us.

455. Do you know what number were bearing upon you at one time?—No.

456. (*Chairman.*) Had you reconnoitred previously to going in on the 18th, and examined what number of guns would be able to bear upon you from Fort Constantine at the positions which you took up?—When we reconnoitred in the 'Fury' nothing had been determined, and we did not know that we could get so close to Fort Constantine; it was only by sounding at night that we were enabled to find a spot in the shoal where we could get.

457. (*Captain Key.*) A sort of bay in the shoal?—Yes.

458. (*Chairman.*) In these reconnoissances, when you were in the 'Fury,' did you never examine to see how many guns could bear upon you from Fort Constantine, supposing you were at 1,000 yards?—We counted all the guns looking to seaward.

459. Were you employed on the debarkation of the army at Old Fort?—I was doing the duty of Flag-lieutenant. I did not land until after the troops had landed. My duty was to make all the signals.

460. But you were Flag-lieutenant during the time that the expedition was fitting out at Varna?—Yes, during the whole time.

461. Are you aware of any particular difficulties which there were in getting the army ashore?—Yes.

462. Will you state them?—Want of conveyance from the ships to the shore.

463. Did not a breeze spring up, and a swell set in, which interrupted the proceeding?—The second day a swell and a breeze sprung up which also increased our difficulties.

464. Supposing that the sea had continued calm as it was on the first day, how long would it have taken to have landed the whole of the troops; you took about 50,000 men over, did you not?—Yes; about 25,000 English and 25,000 French.

465. How long would it have taken to have landed the army complete, with its artillery, commissariat stores, waggons, and other things; could you have done it all by the second day?—It could all have been done by the second day, even with our means; but with properly prepared troop-rafts I think that they could all have been landed between daylight and dark.

466. At what distance were the transports from the shore?—The nearest was about 1,000 yards, I think. The detention was also in consequence of some of the transports anchoring a long way out; it was very difficult to get them all to come in close.

467. They were merchant vessels, I suppose?—Yes; they were merchant ships, and many of the captains were afraid of their ships getting aground.

468. Were the cavalry and artillery horses in the hold of the ship obliged to be swung out?—Yes.

469. Were they then put into boats, or cast loose into the sea?—They were put into boats.

470. How did you get them out of them?—We had prows fitted, which were very good as long as they lasted, but having only been fitted by the carpenters of the ship, a great many of them were lost and broken in the surf; then they had to jump the horses out.

471. You know the beach between Cumberland Fort and Southsea Castle seaward?—Yes.

472. How long do you suppose it would take you under ordinary circumstances in fine weather to land unmolested at that spot the number of troops which you landed at Old Fort? Supposing that you were there for practice, as they are now doing at some places, embarking and disembarking, and that you established yourself there with your fleet with 50,000 men aboard, and all the artillery and stores and things with which you went across to the Crimea, how long would it take you to land the same number of men on that shore?—It would be a matter of calculation how many trips they must make. I should wish to consider this question.

473. You stated that you had insufficient means at Old Fort. I want to know how it happened that the fleet went across with insufficient means, when you had been making such great preparations at Varna; whether it was that you considered that you would be able with the means which you took to land the army without any difficulty, or that you expected to pick anything up there which would assist you?—I stated that there were insufficient means of getting the troops from the ships to the shore: that there were not enough boats, and what boats we had were not available at the moment.

474. Were there none but ships' boats?—We prepared boats the best way we could which we bought at Constantinople, and fitted them with platforms and prows.

475. Native boats?—Native boats; they were very unwieldy. If you were to organise a force to land, and fitted it out from your own dockyards, your boats would be very superior, and much more numerous.

476. What were the arrangements which you made for landing the troops?—Seeing the great delay which would always occur in landing troops without the proper means of conveying them from the ship to the beach, and when at the beach their being able to step out of the boat with ease, I afterwards devised a troop boat only drawing 20 inches water, with a prow such as you see for horse boats towed by steamers; these boats take to pieces, and can be stowed in different parts of the ships, and put together when at the point for landing. By these means every troop ship can carry sufficient boats to disembark all her living cargo in one or more trips as you wish to arrange, by increasing or decreasing the number of boats. It is also necessary to have a number of ladders to each ship, so that the men can get into the boats from many parts of the ship at the same time. Then having a number of tugs. We had only five in the Crimea and two small steamers, the 'Minna' and 'Brenda,' purchased at Constantinople. These boats are made fast in strings, and towed within a certain distance of the beach, when the boats of the fleet would place them on the beach, and the troops would be disembarked, merely having in each of these boats a couple of sailors to steer them, and a couple to attend the painters. You can make boats to take 200 or 150 men, or to take one gun, limbers and horses complete, the horses being able to walk the guns on shore from the boats. I imagine that a well-organised force could land in a very short space of time, if unmolested.

XI.[1]—"Our National Defences." By Captain Cowper Phipps Coles, R.N.

Part I.

The great changes now taking place in instruments of warfare, particularly of naval warfare, having received a fresh impulse from recent experiments, I am induced to publish the following remarks on the all-important question of iron-cased ships. In 1855, previously to the attack on Kinburn, I had recommended to the Admiralty a method of protecting guns by means of iron, to enable us to attack and destroy the Russian forts; and on that occasion, after witnessing the performance of the French floating batteries, I became convinced that we must inevitably come to iron-cased ships. Ever since then my attention has been devoted to the subject. A question which involves the preservation of our maritime supremacy, and with it the national safety, cannot be too much, or too freely, discussed at a moment like the present, when we are daily expending thousands on wooden ships, and are about to expend 11,000,000*l.* on forts for the *partial* protection of our dockyards. I am aware, indeed, that many will differ from the views here put forward; but still think that the evidence which I shall adduce, warrants my feeling increased confidence in the long-formed conclusions which are here submitted to the public.

Let me, in the first place, request attention to the following passage, which is to be found at paragraph 13 of the Commissioners' Report on National Defences:

> 13. "In the line of coast from the Humber to Penzance, which is about 750 miles long, there is an aggregate of nearly 300 miles on which a landing may be effected.
>
> "It would be impossible to fortify, or if fortified to defend, so extended a line of coast, so as to prevent an enemy from effecting a landing, prepared as he would be for a considerable sacrifice of men and matériel."

Again, the same authorities say that they—

> 136. "Have arrived at the conclusion that any system of defence by fortification, that would afford an efficient protection against the bombardment of Sheerness dockyard, by a fleet in the offing, must be so extensive, and the works of so costly a nature, owing to their being constructed in deep water, that it would be unadvisable to recommend the adoption of any permanent defensive measures for this purpose."

In other words, the system of fortifications is only of partial application to our dockyards.

Again, at paragraph 136:—

> "We consider that the force of moveable floating batteries, previously referred to, should be stationed at Sheerness for the purpose of aiding in the defence of the Thames and Medway."

Let us see, in the next place, from the evidence given to the Commissioners, what security against being bombarded by iron ships will be given to our dockyards, or to any fleet of merchant ships taking protection under the guns of these forts at Spithead:—

Admiral Sir R. Dundas says:—

> 6. "The distance from Hurst Castle to the opposite shore of the Isle of Wight being three-quarters of a mile, is perhaps too great to render it absolutely impossible that a ship, or even a number of ships under steam, with a fair wind and a flood tide, should succeed in passing the heaviest batteries which could be constructed."

Admiral Sir Thomas Maitland says:—

> 57. (Speaking of the Needles.)—"I do not think that any number of additional batteries would effectually prevent iron-plated steam-ships from passing."

Captain B. J. Sulivan, R.N., C.B., says:—

> 84. (*Captain Key.*)—"Will you examine the chart of Spithead, with reference to the defence of its eastern entrance, and inform the Commissioners whether you consider that if casemated works of three tiers of guns are placed on Horse Sand and No Man's Land, the anchorage at Spithead will be secure against occupation by an enemy in considerable force

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[1] It is considered interesting to reprint, by permission of the Author, the pamphlet, by Captain Cowper Phipps Coles, R.N., on "Our National Defences (1861);" and also that relating to the Spithead Forts (Appendix XIII., p. 581.)

in the absence of our fleet?—Most certainly not: the forts would be above 2,000 yards apart, and, however strong, could certainly be passed by wooden ships at night, and by iron-cased ones by night or day. It will be almost impossible to hit an advancing ship going at a speed of 10 knots, until she is within 1,200 or 1,500 yards; she will be changing her distance at the rate of about 400 yards a minute, if she has a favourable tide of 2 knots to help her, so that she will only be six minutes within good range; and however true may be the practice with the new guns, the smoke and rapid change of position would prevent a large portion of the shot taking effect even at short ranges."

119. "But we shall always have a powerful means of defence to aid our batteries in iron-cased floating batteries. We ought to be able at Portsmouth to place as many in aid of our forts as could possibly be brought against us."

124. "I do not believe that any fort would prevent vessels going in there at night."

132. (*Captain Key.*) "Do you consider that forts of any size or description would prevent the passage of iron-plated ships through a clear channel, however narrow?—Most certainly not; nor wooden ships by night, if any great object is to be gained by passing: that applies to every channel as wide as these defended by forts."

133. "Not only will iron-plated ships pass batteries easily, but we have especially to fear them, as bombarding vessels, both with guns and mortars. I believe from direct fire they will be safe at 1,000 yards range, if not less."

211. "With iron ships especially, I have no doubt that no stone fort which has ever been built will ever stand fire against them."

Captain Hewlett, R.N., C.B., says:—

244. "But if they are iron-clothed vessels, I believe there are no means of keeping them out, or of preventing them lying quietly mid-channel and bombarding the place, for no shot at two or three thousand yards distance could do them any harm."[1]

251. (*Captain Key.*)—"Do you consider that forts of any size or description would prevent the passage of iron-plated ships through a clear channel?—Most certainly not."

Captain C. P. Coles, R.N., says:—

399. " (*Sir F. Abbott.*)—"Could the forts at Sebastopol have stopped your fleet from going through, if there had been no obstructions?—Certainly not. I would mention, if it is not trespassing, with regard to ships passing forts, that at Kinburn ours and the French gun-boats ran through the channel close to the forts at night without being struck, or, at all events, no casualties occurred, and one of our gun-boats, the 'Cracker,' the next day, in broad daylight, came through the passage, the whole of the forts firing at her."

442. "Within 200 yards."

It is, I think, clear from all this evidence, both of opinion and fact, that the forts in question could neither stop iron-coated ships from forcing a channel, nor prevent a landing between the Humber and Penzance. The recent experiment on Mr. Jones's angulated target has not only confirmed these conclusions, but it has proved that at 200 yards no shell or shot, striking at a certain angle, can penetrate a 4½-in. wrought-iron plate. Be it remarked, too, that in that experiment a greater number of shot struck the target than any ship could have received within the same space, had she been engaged in every action known since the invention of cannon. This experiment, *per se*, was sufficiently significative; but another still more decisive was tried within a few days of it. At Eastbourne, a Martello tower, from 7 feet 3 inches to 9 feet thick, of old and well-cemented brickwork, was breached and destroyed at a distance of 1,032 yards. Not only solid shot, but shell, penetrated the fort, and caused immense destruction. From these foregoing facts, then, we learn firstly, that forts, however numerous, cannot dispute such a passage as the Needles, or Spithead, against iron-coated ships; secondly, that an iron ship, beyond 200 yards, could lie or manœuvre, without the risk of her sides being penetrated (except through the port-holes) by shot or shell from the existing or the proposed forts; whilst on the other hand, at 1,032 yards, she could breach and destroy any fort of masonry with little or no danger to herself.

This is indeed a vast revolution in warfare, much greater than many may realise, and completely turns the tables in favour of iron ships against stone forts. For it must be remembered that these vessels have the power of moving and choosing whatever distance is most advantageous for their own range. That obtained, they can not only destroy the forts, but every object within 9,000 yards.

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[1] It should be observed that the ineffectual fire at Mr. Jones's angulated target at the short distance of even 200 yards had not then taken place.

Now, how does this consideration affect the security of Portsmouth Dockyard? On looking at the Commissioners' map of Spithead, five formidable-looking forts are represented as built out in the sea; with red lines radiating from them in order to convey an idea of their destructive powers against shipping. Inasmuch, however, as it results from what has already been said, that beyond 1,000 yards they can do little harm to iron-coated ships, I have in the map here published drawn around each fort a circle comprising that area. Outside these circles, the portion coloured blue indicates a depth of not less than 30 feet at low water (spring tides), and as within this blue space iron-coated ships can remain without any serious inconvenience from the forts, I will call it "the area of invulnerability." In the next place, with a view to ascertaining where such ships can be placed on this area of invulnerability, within good distance for bombarding the dockyard, let me cite another extract from the report of the Commissioners:—

55. "We have received evidence from high authorities, and we are ourselves persuaded of the fact, that a mass of buildings occupying such an area,[1] and containing such combustible materials as abound in Portsmouth Dockyard, can be set fire to, and almost entirely destroyed, by rifled ordnance at a distance of 8,000 yards."

This radius of 8,000 yards is represented on my map by a yellow circle. (Plate 6.) As, however, of the fifteen ships (marked within it) the nearest to any fort is as much as 1,700 yards, and the furthest 3,000 yards distant, it will be evident that iron-cased ships on the blue space within this circle could bombard and burn the dockyard with almost total impunity, so far as any opposition from the forts is concerned. It will also be seen that through this area of invulnerability, the narrowest passage would be 600 yards wide; so that five ships might steam in abreast without ever being within 1,000 yards of any one of the forts.

Of course, previously to an attack being put into execution, every enemy's captain and pilot would have his station assigned him, and be made thoroughly master of the cross bearings, depth of water, &c., so as to insure taking up these positions with the greatest accuracy, the cross bearings of which might all be got correctly by merely cruising about in peace-time for a day or so, when any sailor versed in such matters would become familiar with the marks, and lay their positions off to a nicety on a chart. Upon that head, therefore, we may rest assured that our intelligent allies across the Channel do not neglect the great facility they have of gaining all information requisite for the pilotage of our harbours.

I do not for a moment presume to point out these positions as being the best for the attacking force, but I affirm with most perfect confidence that they could be taken up with the greatest ease and impunity, in spite of all the forts that can be built. When, too, I remember that the 'Agamemnon' (a wooden ship) led in under the whole fire of the north forts of Sebastopol, and took up, within 800 yards of Fort Constantine, a most difficult position in a small opening in the shoal, with only three feet water under her bottom;—and was indeed so close to the shoal, that when the 'Rodney' gallantly came in to our assistance, although almost touching us, she grounded, in which situation both vessels remained for four hours, receiving comparatively little damage;—I cannot doubt that invulnerable iron ships could take up positions, the nearest at 1,700 yards, and the furthest 3,000 yards from any fort, in the spacious roadstead at Spithead, where they would never have less than 5 fathoms water, even at low water spring tides. However, let us see what the evidence says on this point:—

Mr. R. Stokes, R.N., says:—

568. (*Admiral Elliot.*)—"Would towers on Horse Tail and No Man's Land much assist vessels in entering Spithead, either day or night?—Yes, I think they would."

572. (*Colonel Lefroy.*)—"If an enemy's fleet were entering Spithead by day, in how close order would they be likely to attempt to pass the forts, supposing them to be erected?—Two abreast, half speed (about 7½ knots). If forts were on the shoal, steamers might go at *full speed.*"

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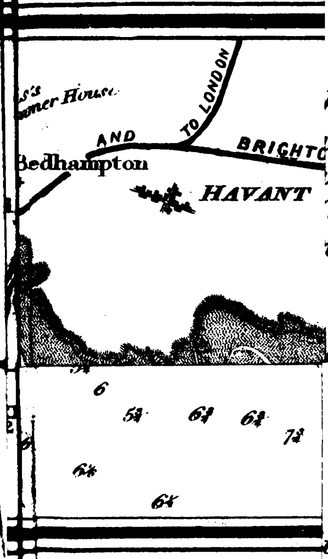
[1] Namely, an area of 551,760 yards.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From these quotations it is evident that even if the beacons and light-vessels were taken away in war time, the risk of ships grounding when running in would be entirely removed, seeing that the forts would still remain as marks whereby to pilot in ships, and enable them to run through at full, instead of half, speed.

All sailors know, when they are making a port at daybreak, or by moonlight, how anxiously they look out for some certain mark. Let us picture then some twenty of these iron-cased ships waiting off St. Helen's, to dash in at daybreak, and discovering through the dawn of day the proposed forts rising out of the water on the very edges of the shoals. No sooner would these unmistakable beacons be caught sight of, than the order would be given, "full speed;" and a child might bring a fleet through. A mere glimpse of the chart may convince us that by our own handiwork, instead of stopping an enemy, we should be giving him perfect facility for running in.

The black lines illustrate the distance from the dockyard, and may convey but a small idea of the tremendous cross fire that could be kept up on it by fifteen ships. Suppose each ship to have a broadside of twenty guns, and every gun to fire forty rounds an hour, not less than 12,800 destructive 100-lb. or 180-lb. shell would fall in one hour into this inflammable mass of stores, shipping and buildings!—Having quoted the Commissioners' paragraph on this subject, it is unnecessary for me further to contemplate the state that Her Majesty's chief dockyard would be in after such a bombardment, or the fatal blow that might thus be dealt to our maritime power—the object so constantly upheld by French writers as their first and great ambition in the event of their again measuring their strength with ours. What, in fact, are our neighbours across the Channel providing at this moment for such emergency?

Lord Clarence Paget lately stated in the House, that the French were building not less than ten iron-cased ships, of which we know that two are launched, and one is actually at sea. Considering the practical experience our allies will thus be enabled to gain, I shall not be surprised to hear that they have laid down the keel of ten more improved 'La Gloires,' while we have only four on the stocks.[1] We may judge how fully alive the French are to the advantages of these formidable vessels, from the following extract from an article in the *Moniteur de la Flotte*. After speaking of the satisfactory results of 'La Gloire,' the writer says:—

> "Again, then, a new era opens for this navy: it is no longer only wooden citadels that the fleet may attack; henceforward it may brave with impunity the most powerfully-defended coasts."

The conclusion is indeed inevitable, that were we to lose (though only for a time) the command of the Channel by our fleet being called away, evaded, or even broken through, our dockyards would be at the mercy of an enemy! Let us then look five years in advance, when we shall have spent £11,000,000 on fortifications, and when iron ships will have more widely taken the place of wooden ones; and again referring to the chart, consider what protection to the dockyards these forts will then be against ten or twenty invulnerable vessels, piloted in by aid of the forts themselves.

The practical question has now to be considered—What other means have we to secure our dockyards and vital points against iron-cased ships? It is submitted that we have but one resource left: we must meet iron-cased ships by iron-cased ships. We must oppose them by vessels of equal (or greater) speed, power of resistance, and destruction. By such means, and by such only, on the approach of a foe, we might at once grapple with him, muzzle to muzzle, and stick to him until one, or both, were sunk; giving him far too much to do to think of bombarding the dockyards. Or if we found that no decisive effect could be made on his plated sides, the engagement would be settled by boarding, after the fashion of olden times, and doubtless with the like success. At all events, any British ship attacked in or near her own port would, when disabled, or in a sinking state, have a far better chance of getting into the dockyard close at hand, than the attacking party, in a similar plight, would have of recrossing the Channel.

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[1] Since writing this, the great exertions being made in France for the construction of these ships fully bear out my predictions.

It may be well, however, before pursuing this subject, to consider the current arguments adduced in favour of the proposed forts. In the first place it is often advanced, "that the vertical fire from the forts would greatly harass their ships, or even destroy them." But I would ask those who reason thus to take into account the small area of a ship in comparison with that of the dockyard. The area of the dockyard is 551,760 square yards; and the area of the largest ship of war that we have, 1,688 yards. Sir W. Armstrong, in his evidence, says:—"At a distance of 8,000 yards, I think that an object occupying an area of 100 yards in depth and 50 in width, would receive about one-third of the shell fired at it from land batteries." In other words, Sir William Armstrong's estimate gives an area of 5,000 square yards; to that we must conclude that the dockyard (a stationary object with an area of 551,760 yards) would receive every shell; but that a moveable ship (with an area only of 1,688 yards) would receive few, if any;—the projectiles falling harmless into the water around her. Nor is the danger diminished by the reflection that, in consequence of each ship being enveloped in smoke, it would be almost impossible for the artillerymen in the forts to ascertain the range; or if by chance that difficulty was overcome, the ship would merely have to alter her position slightly, without betraying the manœuvre to the gunners in the fort, and their range would be entirely thrown out.

This is not the first occasion on which I have adduced reasons for believing that iron-cased ships may be constructed as invulnerable to vertical as to horizontal fire.[1] And although some have urged that the practice of the artillery at Woolwich is now so beautiful that it would be impossible for any ship to withstand their vertical fire, I cannot but think that the reasoners in question forget that firing at fixtures, where the exact distance is known, is one thing; and firing at a moveable ship, the distance of which is not known—amid the smoke of a general action—is another. Besides, shell-firing requires highly-drilled and experienced gunners; and if these forts are to be garrisoned in a hurry, where are such gunners to be found? There seems to me, therefore, no fear of vertical fire against ships, and I cannot bring to my mind an instance of severe damage having been done to shipping by this means, where both objects were not stationary. At all events, in the Baltic and Black Sea, little inconvenience was experienced from it, even by wooden ships.

True, it may be said that the Russian forts succeeded in keeping out the magnificent fleets of the Allies; but in that case nearly all the large ships were sailing-vessels, inflammable and not invulnerable; and there were no 'La Gloires,' or 'Warriors,' and no rifled cannon. What would have been the fate of Cronstadt or Sweaborg if there had been? The truth, however, is, that it was not so much the forts that kept out the allied fleets as the shallow water, the barriers, and the powerful fleets behind the forts; and the consideration that if the attempt to force the barriers and passage were made, and should fail, these fleets would come out and engage our damaged ships with great advantage. I can answer for such having been the case in the Black Sea, where, let it be observed, there was not that fall of tide which we have at Spithead, exposing all the masonry, and the very foundation of the forts, to the broadsides of ships capable of choosing their own distance. It seems, therefore, more to the purpose to remember how the walls were brought down by a few broadsides at Bomarsund, and how the Martello tower, at 1,032 yards, was destroyed at Eastbourne. If it be objected that the proposed forts may be rendered indestructible by being themselves constructed of iron, the answer is,—First, their cost will be enormous; and, secondly, that this will not enable them to destroy vessels of equal indestructibility. As regards our Crimean experience on the latter point, although the efficiency of forts against wooden ships would not prove their efficiency against iron ones, it must not be forgotten that the 'Agamemnon' and 'Sanspareil' remained four hours under the cross fire of both the North and South Forts of Sebastopol; that the English and French gunboats ràn through the narrow passage at Kinburn; and last, not least, that the gallant little 'Cracker'—a frail gunboat—ran through it twice, the whole of the forts firing at her without her receiving any serious damage.

In the next place, Spithead must be looked upon in time of war as a harbour of refuge, not only for ships of war refitting, but for fleets of merchant vessels laden with the wealth of the country. What protection, I would ask, can be afforded to such fleets by the proposed forts? If a number of iron-cased ships wanted to destroy or capture these inviting prizes, their course would be clear. Having the forts to serve them as beacons, they would run in at full speed alongside and among this mass of shipping; when being enveloped in smoke (our best friend and protector in action), it would puzzle the cleverest artillerymen in these *casemated* forts to discern friend from foe; and even if they could, they would not dare to fire, for it would be almost impossible to hit the one without the other. Conceive the resulting confusion, so purely advantageous to the attacking force, who, having picked up those vessels worth capturing, and set fire to the rest with molten iron shell, would next despatch a few ships for the destruction of Southampton, Osborne, Ryde, Cowes—each and all of them being approachable within 5 miles range. It may be replied that no one proposes to rely on forts alone, but upon forts with iron-cased ships to assist them.[1] Be it so; but still the question remains: in what way would such ships be assisted by the forts? Surely the same argument must hold good in this case as in the former: namely, that when the attacking ships were alongside your own, it would be impossible for the forts to fire at one and not the other; and hence that they would be practically useless, as useless, in fact, as field artillery at the moment when two opposed lines are crossing bayonets.

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[1] See Lecture delivered in the Royal United Service Institution on July 29, 1860. Mitchell, 39, Charing Cross.

We are now in a position to deal with the stock argument that forts are, at any rate, superior to iron-cased ships in this respect; that the latter are liable to be absent when they are most wanted, whilst the former are stationary. If forts will neither stop such ships from coming in, or from bombarding the dockyard, of what use is the stationary quality so highly vaunted? But more than this. In the present age of rapid movements, the fact of isolated forts being stationary is in reality their weakest point: they may be taken in detail. One may be attacked and overcome; but the rest cannot come to its assistance. On the other hand, ships can move for mutual support, and concentrate their whole force on the enemy, at the most suitable range, wherever he may make his attack. In consequence of this risk, experience shows that few forts have been built without its having been found that they require others to protect them, involving of course fresh expense and additional garrisons. And here again let me refer to the chart of Spithead. Does it warrant us in expecting any exception to the rule? I, for one, do not doubt that after the proposed forts are built, it will be discovered how necessary it is to build another on the shoal called the Ryde Middle, in order to prevent ships lying in Stokes Bay, where according to the present plan, they could lie with impunity. And so we might go on until we had placed a fort on every shoal down to the Needles, and then not be a bit the more secure after all.[2]

There is another risk arising from the stationary character of the forts upon which I need not dwell,—that of rendering the garrisons liable to destruction by the process proposed by the much-lamented and noble Earl of Dundonald.[3] Supposing that this process has the efficacy ascribed to it, it would follow that the victims being unable to get out of the way, the attacking ships would only have to choose their distance; and after carrying the process into effect, they would quietly run alongside and take possession, turning these forts against the dockyard. Apart, however, from this risk, light-draught ships could certainly be laid alongside each fort at half-tide, and board it with an overwhelming force, commencing with the Horse-sand and No Man's Land, and taking all the others in detail. The rest of the ships might of course cover those who were boarding from the fire of the other forts.

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[1] Iron-cased ships were recommended by the committee of naval officers attached to the Royal Commissioners on our National Defences, but no money or steps have been taken for their construction.

[2] Since writing this I have discussed the subject with an engineer officer, who was warm in justification of the forts; but who so far verified my words, that he actually proposed building the additional forts marked in the chart with Nos. 1, 2, 3, 4, 5. It will be seen that Nos. 1, 2, 3 are in 12-fathom, No. 4 in 9-fathom at low-water, and No. 5 is on the very shoal (Ryde Middle) above referred to. I will say nothing of the expense and inexpediency of building these forts in deep water; I merely allude to this officer's suggestion as a confession that the proposed forts will not keep iron ships off. And I would ask, if these supplementary forts are already proposed before the others are even commenced, how many more will be found necessary before the arrangement is completed? I fear the truth is, that if this system be once commenced, there will always be some weak point discovered, and a continual appeal for more forts.

[3] See his second volume, p. 234. *Report of Commissioners.*—" We consider that, under many particular circumstances, this method of his lordship may be made available as well by land as by sea, and we therefore suggest that a record of this part of Lord

We next come to the argument of economy. Forts, it has been contended, are less costly than ships, because they are more durable. The answer is obvious. The value of an engine of war is measured by its efficiency, and if forts will neither stop an iron vessel nor prevent her from bombarding the dockyard, they are extravagantly dear at any price. Even *one* iron ship might stop at least one other, by engaging her muzzle to muzzle, running down or boarding her; *but I defy the whole of the proposed forts to stop even one iron-cased ship.*

It must also be remembered that it will be four years before these forts are completed, and we all know that making a contract is one thing, and fulfilling it is another.[1] But even supposing the contract carried out punctually, iron-cased ships could be completely built while the mere foundations of these isolated forts are being laid down. All the materials having to be carried by vessels to an exposed place like Spithead, little could be done in the winter months. Next, let us consider the chance of these forts being only half-finished, and not ready to receive their guns in the event of a rupture with France. Then, indeed, would

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Dundonald's plans should be deposited with the Admiralty, to be made use of when, in the judgment of their Lordships, the opportunity of employing it may occur.

"We assume it to be possible that the plan *contains power for producing the sweeping destruction the inventor ascribes to it.*

"We feel *that great credit is due to Lord Dundonald for the right feelings which prompted him not to disclose his secret plans when serving in war as naval commander-in-chief of the forces of other nations, under very trying circumstances, in the conviction that those plans might eventually be of the highest importance to his own country.*"

(Signed) "THOMAS HASTINGS, Captain R.N. and
Principal Storekeeper.
"J. F. BURGOYNE.
"J. S. COLQUHOUN, Lieut.-Colonel R.A.

"Let the public now judge of the nature and value of those plans—of the merit of never having disclosed them, though exposed to severely trying circumstances, and also whether they are impracticable.

"I have been told, on indubitable authority, that during the late war with Russia an interchange of warlike plans took place between the English and French Governments, [even our signal-books were given them, C. P. C]. It was further pointed out to me but the other day, that a French journal of high authority had remarked to this effect:—'*Should a war arise between England and France, the latter power would bring warlike engines into play to which rifled cannon were a trifle.*' From this I make little doubt but that my plans *are* known to the French Government; and if so, whenever they are applied, the people of this country will find them no 'trifle,' for as the Report just adduced infers, no power on earth can stand against them.

Again (page 241): "I am not certain whether—were the plans disclosed—the advantage would not be in favour of publicity. Such disclosure would demonstrate that there could be no security in coast defences and other stationary asylums, on the construction of which it is now proposed to spend so many millions of the public money. It would show the inexpediency of an expenditure of ten (which may mean twenty) millions for the construction of forts and harbours, instead of employing half the amount to remodel and renovate the navy. The disclosure might have the effect of preventing useless expenditure, and of averting the danger of future parsimonious naval administration, by leading to the adoption of essential measures of nautical improvement, by which alone the safety of the country can be preserved."

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[1] These forts will, I believe, cost treble the original contract.

they serve as unmistakable and harmless beacons to assist an enemy in running in; and nothing could save them from being taken, and employed to cover the attacking force from fire of the batteries on shore.

Were we, on the other hand, to rely on iron vessels, we know that a ship, when she is in the course of construction, is housed in together with all the material around her. Not subject to being retarded by the seasons, she there remains secure, until launched into the element on which she is to meet her foe. The slip she has come from is then left ready for the construction of her successor, with such improvements as may be suggested by the detection of defects in her own case, or by the advance of modern science.

Again, there is no reason why we should not in the next five years increase our range as much as we have done in the last five. Indeed, Sir William Armstrong says, that hitherto he has not tried for range. Supposing, then, that we should (as I verily believe we shall) make such an advance, the consequence might be that ships could lie outside of these forts off the Warner,[1] and bombard the dockyard without even taking the trouble of coming into Spithead. As the forts could not be advanced to drive them off, your only resource would then be seen by the most incredulous to lie in the moveable batteries of your ships.

And here I would remark, that although I have selected Spithead for an example, the arguments I have used apply to all our dockyards, and to some of them indeed in a still greater degree. Nor are our neighbours across the water unconcerned in the question; seeing that Cherbourg (in particular) can be approached within 4,000 yards of the Bassin Napoléon III. and shelled, without the attacking vessels coming within 1,000 yards of a fort.

Let me, in conclusion, meet one more objection which possibly may be raised. I may be accused of exposing our weak points, and of inviting a foe to attack us. My answer is, that those weak points will not in fact exist until we shall have saddled ourselves with those isolated stationary forts, and being blinded by a false security, shall have neglected our moveable fortresses and allowed our rivals to outstrip us in the race of building iron-cased ships. In that race the French have already taken the lead, and we may be confident that they will use every effort to keep it. Surely Napoléon III. has something beyond an "idea," to stimulate him in constructing those costly vessels. We cannot shut our eyes to the future; and so deep are my convictions of the importance of the vast struggle for supremacy of the sea, and of the great revolution which is about to alter the nature of warfare, that I trust I may be forgiven for reproducing here the last paragraph of my lecture on Iron Ships :—

> "Now that other nations are building iron-coated ships, we cannot stop. In future our fleets must fight in armour; and the supremacy afloat must depend henceforth on superior ability to produce the new ships required. The first outlay for iron-coated ships will no doubt be enormous; but looking to the future, the great strides we are making in rifled cannon, in motive power, and in invulnerable ships, the *reconstruction* of the *large* ships of fleets which decide the fate of nations is inevitable. Three-deckers, and stationary guns on the present system of fortifications for coast defences, will become obsolete, and we shall look upon them as we now do upon the old stage-coach, which is only used when we can get nothing better. The most economical ship will be that which is the most invulnerable and the most durable."

These were my conclusions after seeing the French floating batteries at Kinburn. Since then I have devoted much time and attention to this subject; and I feel that however hard it may be to give up our romantic ideas about "the wooden walls of Old England," that disenchantment must be accomplished; and not only must we adopt iron vessels to defend the coast, but (eventually) they must supersede our splendid line-of-battle ships. In point of expense, it must be remembered that any one of these iron vessels, costly as they are, could cope with and destroy at least three line-of-battle ships; nay, if judiciously handled, would be more than a match for any amount of such inflammable wooden targets. At the same time, let me not be misconstrued. I am not contending against the utility of forts in other and very different positions. By all means strengthen the present forts we have, and construct such as may be necessary to protect the roadsteads of our arsenals. Above all, let every such fort be supplied with the most improved description of ordnance. It is the projected isolated forts in the sea that I condemn; and I own myself deeply impressed with the necessity of empowering a committee of practical and scientific men to decide, without loss of time, on the best mode of constructing invulnerable vessels wherewith to meet those iron-cased ships now built, and in progress, on the other side of the Channel. This is the only way of securing to the country the most durable and serviceable article for its money. For, in the matter of National Defence, it must be remembered, that every shilling spent in the wrong channel is worse than thrown away; since it necessarily entails the further cost of retrieving, or trying to retrieve, our blunders.

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[1] Mr. Thomas's and Mr. Whitworth's guns have already attained a range of 10,000 yards.

PART II.

HAVING so far shown what inadequate protection these isolated forts would afford against the present engines of war, and pointed out the changes which we may in a few years anticipate, it becomes necessary not only to advert to the organisation of a force for the protection of our dockyards, or any local point, but to consider the general defence of the United Kingdom, and more particularly of that of the Capital.

It appears that hitherto only defences for the dockyards have been considered and proposed, and that we have all more or less drifted into the assumption that, should the impending storm burst, which the Prime Minister has declared "may happen at any moment," we are not only in great danger, but that if a landing were attempted we could not prevent it. Hence our study has been to protect our dockyards, leaving the very heart of the country, the Capital, as unprotected as ever. Where would the enemy first go? "They would make for the Capital." But why not first consider how to prevent the possibility of a landing, and secondly, how to dispose of an enemy should he succeed in landing. Let the country feel that not only our dockyards, but the Capital, and every homestead in England are secure, and beyond the grasp of a foe.

How then can we attain the first and great point, that of preventing a landing?

Now our first object must be, to organise a general system of defence, such as that one branch, or service, may be at once independent of the other, and able to act in unity with it, thus bringing into play the whole strength of the country on any one or more points which the enemy may attack. I shall therefore throughout consider this as the first and great principle of warfare, the importance of which is now so greatly enhanced by the introduction of steam, which presents as great facility for speedy movements by land and sea, as does the electric telegraph for the rapid communication of intelligence.

Although economy must be considered, it should be remembered that the most efficient engine of war is the most economical; first, because the knowledge of our being armed with the most effective engines of war tends to prevent an attack; and, secondly, because, when attacked, they will insure our success in repelling and chastising the enemy.

I propose, then, to consider the different lines of defence in their order of importance:—

1st. Our Fleet.
2nd. Our Coast Patrol of Iron-Cased Ships, expressly for Coast Defences.
3rd. Our Army, Militia, and Volunteers.
4th. Fortifications, including Earthworks.

Our Navy is admitted by all to be our chief line of defence for the protection of our Colonies, commerce, and command of the Channel. So long as we remain sovereign of the seas our prosperity is unchecked, but woe to England when she loses her supremacy at sea. "Twenty-four hours' command of the Channel is invasion," and "twenty-four days' loss of the command of the sea is ruin to our credit, our commerce, and our manufactures." But it is said by many that our Navy has ceased to maintain that supremacy which it boasted before the introduction of steam, electric telegraph, and the vast subsequent improvements in engines of war. It remains, however, to be seen whether those improvements cannot be turned to our benefit, and give us tenfold the power we had in former times, when our means of closing with an enemy solely depended upon the uncertain elements of wind and tide. These could only be made available as long as the unprotected masts, sails, and numerous ropes were not disabled by the enemy's shot and inflammable projectiles. Steam has now given us the power, where we have the will, of closing and grappling with a foe, at any speed up to 15 knots, or of taking up the most advantageous position against stationary forts or vessels of less speed than that of our own. The vast power of the marine steam engine, invulnerable for all practical purposes, from its position below the water-line of the vessel, is surely very superior to that of masts, ropes, and sails, exposed as they are to every shot that may be fired.

It has been said, steam has shortened the passage across the Channel, and given greater facilities to an invading force. Has it not on the other hand (as often remarked), given an equal facility for intercepting that force, or concentrating our forces at any given point on our coast? An invading force of any magnitude, crowded into numerous vessels, covering many miles of ocean, must be seen at some distance in moderate weather (in which only a landing could be effected). Our steam fleet will thus have ample warning to enable them to attack this moving forest of ships, with their living cargoes, on their way across the Channel. Much more in the confusion of landing will our free and unfettered fleet, from rapidity of movement, possess an undeniable advantage. Wherever the enemy's fleet steer, there we can follow them, independent alike of wind and tide. Our security must not depend on stationary engines of war. These can but be used for defence in the particular locality to which their action is limited. Great Britain, if called on to unfold her strength, should be ready to play an offensive, rather than a defensive game; to attack, rather than abide the attack, and in the management of her engines of war should avail herself of all modern appliances for insuring the utmost rapidity of movement. No sooner should a fleet leave an enemy's port than ours should engage it, and strike the first blow, before a combination of forces against us could be effected. In olden times an enemy's fleet might have slipped out and got to the eastward, while our own might have been detained westward by a foul wind, or even kept in port. No fear of this in these days of steam, *electric telegraph*, and lights. You can now steam to any intermediate place between our great harbours and arsenals in as many hours as formerly it would have taken a fleet to beat out of Plymouth. Formerly our fleet might be blown off, and, light winds succeeding the gale, many days might elapse before they could again sight the land.

In these days of "steam," "down screw," "up steam," in a few hours you can make the land. Where then is our inferiority in consequence of steam? Other nations, it may be urged, can do the same! But other nations have not our power and means of building fleets and iron-cased ships, nor of constructing engines and rifled cannons.

We possess unlimited supply of iron and coal. We are the best mechanics and engineers in the world, and last, though not least, may challenge it both in the number and superiority of our sailors, having at this moment more than 300,000 British seamen afloat on the ocean, if we only take advantage of them.[1]

These are the natural resources with which Providence has blessed this island. Let the energy of the nation be thrown into the right channel. Let her open her eyes to the value of her first line of defence,—a line which has never failed, —and I think we have little to fear.

It is said that our fleet may be evaded, or called away for the protection of our colonies and commerce; and we will assume this to be the case, and consider what is to be our second line of defence.

On this subject, a sound and able pamphlet has been written by Colonel Alexander, "The Command of the Channel, and the Safety of our Shores."[2] I can only say how heartily I concur with him in the main object in view, and sincerely hope he will not relinquish the task he has so ably commenced, of pointing out to the country its true and great defence. My method of creating a second line of defence is, I may say, identical with that of Colonel Alexander's, viz., constituting a defence expressly for the coast and our dockyards, quite irrespective and independent of our sea-going fleet, which would then be left free to protect our vast commerce and colonies, and capable, when opportunity offered, of striking a decisive blow against the enemy. Let us see what facilities we possess in order to constitute this force.[1]

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[1] *Vide* the Author's letter to the Duke of Somerset on "Manning the Navy," August, 1860. Bradbury and Evans, 11, Bouverie Street.

[2] Published by Messrs. Bradbury and Evans, 11, Bouverie Street.

We know that steamers are now built, and daily contracted for, to make the voyage to America at a given average speed; and we know, moreover, that intelligence can be conveyed by the electric telegraph in a given number of seconds. Why then should we not have vessels stationed at different points, patrolling our shores, and ready, on the first telegraph of "approaching hostile force," to concentrate on one point?[2]

To carry this out, you would require twenty iron-cased ships constructed expressly for coast purposes. It would be necessary to give them great speed, and to attach to every two ships a tender. These tenders would be vessels of about 150 feet long, with capacity both for speed and turning rapidly. They should carry two heavy guns, and be of weight and speed sufficient to enable them to close on an opponent. This force would be stationed at our different arsenals, and kept in the highest state of efficiency, ready to act on a moment's warning.

This flotilla would patrol our shores alike in peace or war, thus giving the officers a most accurate knowledge of our coast, and enabling them to avail themselves of every advantage when guarding against or attacking an enemy. To insure rapid intelligence, the electric wires must be led round our coast, and at all the prominent points there should be a station, with the means of communicating by night,[3] and of making day-signals to the cruisers and gun-boats, who would keep us *au fait* of all that was going on in the Channel, and in our neighbour's harbours.

At each of our naval ports, such as Plymouth, Portland, and Portsmouth, there should be a floating telegraph station, near which the admiral, or senior officer, of this coast flotilla would anchor, so as to insure the communication of intelligence without delay. The simultaneous transmission of orders by the electric wire would admit of a correspondingly simultaneous action on the part of the entire force wherever dispersed.

These twenty iron ships, possessing an average speed of 12 miles an hour,[4] would close on an enemy who attempted either to bombard a dockyard or land between these different stations. Were he to venture an attack northward of the Land's End or the South Foreland, he would have the whole force of these twenty ships ready to close on his rear, cut off his retreat, and all communication from his own port.

In looking at the map of the Channel, it will be seen that the distance between these points (assuming 12 knots as the average speed) can be measured by so many hours, for instance :

	Miles.	Hours.	Min.
Plymouth to Portland . .	100	8	20
Portland to Portsmouth . .	75	6	15
Portsmouth to the Downs . .	140	11	40
Downs to Sheerness . . .	60	5	—

It must be remembered that, were an enemy to appear in force at any intermediate point off the coast between these places, the distances and times must be proportionately reduced. Thus, to attack a force midway between Portland and Plymouth, these iron-cased ships would be on the spot four hours and twenty minutes after notice given by the cruisers and telegraph stations. Even assuming everything in favour of the invader, he has to bring his ships in, to anchor them, to put his men in the boats,[1] to propel the boats on shore, and then discharge their living cargoes; against which I imagine volunteer artillery and riflemen would be meanwhile amusing themselves to some purpose. What force could be landed on a hostile shore thus fore-armed?

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[1] See Lecture delivered at the United Service Institution, June 29th, 1860, "Shot-Proof Gun Shields." Mitchell, 39, Charing Cross.

[2] See map, with notes.

[3] Professor Way's electric light would be admirable for this purpose.

[4] This is the minimum. They ought to be built to make 15 knots, and at that speed nothing could get away from them.

It will indeed be a bold and reckless invader who makes the attempt, or ventures to bombard a dockyard in the face of this coast patrol, ready as it would be to attack him, to cut him off as soon as he left his own ports; or at all events, able to annihilate him before he left our shore, on which he would have, at the utmost, only succeeded in causing some little alarm and damage.

Now, what would these iron ships cost? About six millions; and to maintain this force in readiness for action would require an outlay equal to that demanded by four line-of-battle ships while in commission. This force could be called into existence in a single year. The construction of the forts proposed will extend over a period of four years, will cost nearly double the above sum, and the result will only extend to the partial defence of our *Dockyards*. Even should an enemy succeed in forcing these two lines of defence, namely, that of our sea-going fleet, and that of our coast patrol, he would, I think, find himself too much weakened to attempt an encounter with the stubborn resistance he must meet from our Army, Militia, and Volunteers. As the old song goes:

> "But should their flat bottoms in darkness get o'er,
> They still will find Britons to meet them on shore."

When, as now is the case, by the help of the Armstrong cannon, a movable speck of a gunboat, or iron ship, can lie five miles off shore, and bombard a tower or arsenal with little chance of being hit by forts, that nation which commands the sea must command the world, from its power of laying waste all within range of her deadly sting of 5 miles length. One of the arguments used against these iron-cased ships, whose speed enables them to concentrate their power on the enemy (thus giving them so great a superiority over isolated stationary bodies) is, that they may not be at the right spot at the right time. This argument, which has already been referred to in the first portion of these remarks, is open to the further reply, that it is founded on the assumption that the Admiralty (or such other department as might have the control of these vessels) would be incapable of directing them in case of attack. But what objection, I am asked, is there to stationary forts? Simply the objection which might be urged against a scheme for taking away the horses from the artillery, in order to plant the guns about in the most likely spot for an invader, or to fettering the legs of our Volunteers, and planting them round London, to insure their being quite in the right place![2]

Having thus far discussed our sea defences, I will touch lightly upon our land resources, and take the Army, Militia, and Riflemen as a fourth, and aggregate, line of defence. Let us suppose that an enemy has broken through our fleet and floating coast-guard of iron ships. The job has been a tough one to say the least, and with a caution induced by the necessity of recovering breath after it, the force is disembarking *out of the range of the proposed forts*. How are they now to avail us? The alarm is telegraphed; what part are these forts to play? That of the mountain towards Mahomet; with the single but important difference, that Mahomet knows far better than to come and meet the mountain. Are we then to wait for an attack which the enemy is too wise to commence? The waiting game is, at best, not the game which the Englishman likes best to play. He would prefer leading off under any circumstances; and if compelled to avail himself of these forts in the only manner in which they can be made available, by waiting behind their shelter, he will not prove a very apt scholar, under circumstances so little favourable to a lesson in the game of patience. *Motion* is the genius of modern warfare, as *Station* (if I may venture on the word) is that of days gone by. We have now the nucleus of a moving force assuredly more available than the stationary forts whose nominal cost is to be eleven millions, and that moving force of riflemen cost the Government, we may say, *nothing!*

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[1] It has been said they would tow boats across with troops in them. This, however, is a ridiculous supposition. Our fast steamers, if ever so small, would run down and destroy thousands of them.

[2] Autobiography of the Earl of Dundonald, vol. ii., p. 242.—"Why should an enemy go to a coast fortification when he can land miles away from it? I will take the instance of the Dover fortifications, which are amongst the most stupendous in the country. What is there to prevent an enemy from landing at Walmer, where there is nothing to oppose him but the six popguns in the flower-garden of the castle?" Again he says: "Lastly, when disembarked at Walmer, the fortifications of Dover could not in the slightest degree interrupt the enemy's communications by sea. Nothing but an efficient navy could do that; and with an efficient navy the disembarkation at Walmer could never be attempted. All this is plain enough; for, after all, military tactics are founded on common sense, and the amount of common sense decides their superiority."

A glance at Bradshaw's Railway Map (Plate 7) presents us with a network of railways and electric telegraphs, available (with a little previous organisation and connection of lines) for throwing a force on any part of our coast, in numbers adequate to resist the landing of any invader, and with a rapidity only limited by the speed of our locomotives. On the flanks and rear of the invading fleet, our floating batteries would offer their services; and in their front our riflemen would speak a welcome from every bush and tuft of grass, and from every inequality presented by the beach; of which they would not be slow to take advantage, and which would render them invisible to, and therefore safe from, the artillery of the ships. A deadly welcome it would prove to the masses of human beings packed closely in frail boats; which would serve as distinct marks, and which would be sunk as easily by a 6- as by a 100-lb. shot. Only let us have flying artillery, and riflemen who would move along the shore, or to any part of our coast, in conjunction with a floating patrol, and I do not see how a landing can by any chance be effected. We have already a sea-way round our island far better than any railway that the hand of man can make, and not liable to those accidents of daily occurrence to which the latter is subject. Railway communications may be destroyed, and interrupted by the hand of man, but the sea-way with which God has blessed us can be disturbed by Himself alone. And its disturbance, while an additional security against the landing of a foe, is at the same time little impediment to the purposes to which in our own case it is applicable. Aided by steam, we can move any amount of guns and men through a sea which would render any chance of landing hopeless; and the gale which would prevent our doing so would confine our enemies to their own ports.

The result of this year's work has been a proud and hopeful one in the inauguration and establishment of the Volunteer movement.[1] Let the experiment be made of moving them in sufficient bodies, and with the utmost practicable rapidity, to a supposed point of attack by sea, from the different entrenched camps which they should occupy in readiness for the signal. The lesson would, methinks, be valuable, if only as tending to allay our continual panics of an invasion and its consequences.

The discussion of this plan, however, is more proper to a soldier than to a sailor like myself, and has already been considered by one of our ablest military authorities. But it is evident that these eleven millions' worth of coast forts will neither protect London, nor prevent a landing, or the destruction of our dockyards by sea. Cannot, then, these same eleven millions be laid out to better advantage? Is not a coast patrol such as I have described—in other words, a general system of *moveable* defence—worthy of attention? Our aim should be, firstly, by a floating coast patrol to render a landing as *impracticable as possible*, on the sound principle that prevention is better than cure. And, secondly, to maintain in efficiency such a force as to enable us to render a good account of an enemy, should they so far succeed as to annihilate that coast patrol, or what is equally probable, catch it asleep.

The building of the proposed forts will necessitate the dispersion, instead of the concentration, of our forces, and will root them to the spot instead of aiding and turning to account their mobility.

Concentration and mobility will, in my humble judgment, now effect more for the protection of England's coast, and England's metropolis, than any fortifications though built of gold itself. Forts in these days of long range (which we

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[1] This was intended to have been published in September, 1860, but some difficulties about the maps delayed it.

MAP OF G
h
Banff
Philoth
Old Deer & Mintlaw

OF IRELAND PLATE 7, VOL. XX.

may daily expect to increase) I consider mere *man-traps*, excellent, if the object is to shut men up for the purpose of being harassed or destroyed. Such must be the inevitable result of a vertical fire from numerous guns placed around at a radius say of five miles, the guns being afloat or on land, as the case may be, and with their fire converging on the large area of stationary forts, whose diverging fire would be comparatively harmless on the moveable guns around it. It is well known that even military authorities differ about the expediency of these vast fortifications (as, for instance, in the case of Portsdown Hill); and I confess to sharing their doubts. I may be accused of advocating too partially my own element, the sea; but I feel that in what I am here advancing I am only doing my duty to my country, whose first and most natural defence is the sea—a defence, moreover, consistent with all modern improvements in the art of war. Our maritime supremacy is the very heart of our existence. Once let us lose this, even but a short time, and we are no longer a first-rate power. To sum up, my great object has been to show that in these days of mechanical improvements, our safety must depend upon rapid movements of our combined forces by sea and land, and not on the old system of stationary forts, and of guns scattered over the country. In a word, I have sought to urge the direction of our energies in what appears their safest and best line—the British Channel and its fleets.

Again, the Earl of Dundonald says (page 244, vol. ii.):—

"Full discussion of this matter would, however, require more space than can here be devoted to it; and should my life be spared, I will, on a future occasion, enter more extensively into this and other cognate subjects. Were I now to do so, I am afraid public faith in some of its newly-cherished fortifications would be materially shaken, and will therefore refrain from so doing, in the hope that improvements in our navy, the only true basis of national safety, will render such remarks unnecessary.

"In short, immoveable stations of defence, as a protection against invasion, are not only costly and of doubtful utility, but a *reliance on them* is, in my mind, an indication of a declining state. It is little short of national imbecility to suppose that, because we erect imposing fortifications, an enemy *will come to them!* when he can operate elsewhere without the slightest regard to them; and the more so as the common experience of warfare will tell him that numerous fortifications are in the highest degree national weakness, by splitting into detail the army which ought to be in the field against him, but who are compelled to remain and take care of their fortifications. Yet *half the sum* required for fortifications as defences in case of war would suffice to place the navy in a condition of affording far more effectual protection. There is no security equal to that which may be obtained *by putting it out of the power of an enemy to execute hostile intentions.* This can never be effected by forts, but may be accomplished by adoption of proper measures, which I shall at present refrain from commenting on."

Those who may favour me with a perusal of my views will readily understand how gratified I felt when, after having written them, I read the above quotations from the Earl of Dundonald's work, so entirely coinciding with my opinions. Thus encouraged by so able an authority, I shall not relax in my endeavours to point out what I believe to be the right channel for our defences, into which the energies of the country should be thrown. The above is a mere outline. I propose, if permitted, to enter into further details hereafter.

XII.—SPITHEAD FORTS.—Return to an Address of the Honourable The House of Commons, dated 3rd May, 1861;—for,

COPY of Report of the Commissioners for National Defences, and Letters from General BURGOYNE and Sir WILLIAM ARMSTRONG to the Secretary of State for War, relative to the Spithead Forts.

War Office, May 5, 1861. T. G. BARING.

LETTER addressed by the Royal Commissioners on National Defences to the Secretary of State for War, relative to the proposed Substitution of Iron-cased Vessels for the Forts at Spithead, recommended in their Report of 7th February 1860; together with a Memorandum by Sir J. BURGOYNE, and a Letter from Sir W. ARMSTRONG, upon the same subject.

LETTER from the Secretary of State for War to Lieutenant-General Sir H. D. JONES, K.C.B.

SIR, *War Office, Pall Mall, S.W.*, 18*th February*, 1861.

I AM directed by Lord Herbert to transmit to you the accompanying copy of a letter, dated the 11th instant, addressed to his Lordship by his Royal Highness the President of the Defence Committee, covering one from Vice-Admiral Sir Richard Dundas, of the 8th instant, suggesting "the possible substitution of iron-cased ships in certain localities for such of the permanent defences as can be constructed only at large cost, and cannot, in all probability, be completed for a long period of time."

Lord Herbert is of opinion that, whatever view may be taken of the question, it is one of the greatest importance, and requests that the suggestions of the Vice-Admiral may be considered by the Royal Commission which reported last year on the Fortifications of the Dockyards and Arsenals, of which you were President, or by those members of the Commission now in England.

In connection with the same subject, his Lordship further wishes the Commission to consider the points referred to in a late pamphlet by Captain Coles, R.N., and in another pamphlet, just printed, intituled "Reflections on the Navy," translated from the French.

The question appears to Lord Herbert to be—

1st. Whether the plan last year decided on of building three forts, instead of five, and supplementing them by iron-cased floating batteries, should be persisted in; or,

2ndly. Whether the mixed defence should be abandoned, and one consisting of floating batteries only should be adopted; or, lastly,

3rdly. Whether in any case the floating batteries necessary to both plans, or some of them, should not at once be commenced.

Lord Herbert begs that the Commission will propose whatever modifications of their previous recommendations additional experience may suggest, and he has only further to express a hope that the matter may be taken into consideration, and reported on with the least possible delay.

I have, &c.,
(Signed) EDWARD LUGARD.

Lieutenant-General Sir H. D. Jones, K.C.B.,
&c. &c. &c.

P.S.—The return of Vice-Admiral Sir R. Dundas's letter is requested.

LETTER from His Royal Highness the DUKE OF CAMBRIDGE to the Secretary of State for War.

MY LORD, *Horse Guards*, 11*th February*, 1861.

I HAVE the honour to forward to your Lordship the accompanying letter, dated 8th instant, addressed by Vice-Admiral Sir Richard Dundas to the Secretary of the Defence Committee, suggesting "the possible substitution of iron-cased ships in certain localities for such of the permanent defences as can be constructed only at large cost, and cannot in all probability be completed for a long period of time."

I have further the honour to request that your Lordship will cause the suggestions in question to be referred for the consideration of the amalgamated Defence and Fortification Committees.

I have, &c.,
(Signed) GEORGE.

The Right Honourable Lord Herbert.

LETTER from Vice-Admiral Sir R. S. DUNDAS to the Secretary of the Defence Commission.

SIR, *Admiralty, Whitehall*, 8*th February*, 1861.

HAVING been called upon, as a member of the Board of Admiralty, to take part in the discussions of the Defence Committee, and having assented, in common with His Royal Highness the Duke of Cambridge, and with other members of the Committee, to a Report conveying to the Secretary of State for War the general concurrence of the Committee in the views expressed in the Report of the 7th of February, 1860, by the Commissioners appointed by Her Majesty to consider the condition and sufficiency of the fortifications then existing for the defence of the United Kingdom, I am anxious to call the attention of the Committee to the following considerations; and I have to request that, with the approval of His Royal Highness, they may be brought under the notice of the Committee at the earliest convenient opportunity.

At the date of the above-named Report of the Commissioners, it is not to be denied that the subject of iron-cased floating batteries had not been overlooked. In estimating also the advantages of fixed forts or batteries, such as those recommended to be constructed for the defence of Spithead, and of extensive roadsteads not easily commanded from the shore, many details were entered into, pointing out the various modes and circumstances in which floating batteries might be employed as auxiliaries to such forts, and it is impossible for me not to concur in the general observations of the Commissioners upon this part of the subject.

It appears to me to be nevertheless important to suggest, for the consideration of the Defence Committee, the expediency of modifying, to a certain extent, and before it be too late, the recommendations of the Committee in so far as they relate to the construction of some of the most costly batteries, and I would suggest the possible substitution of iron-cased ships in certain localities for such of the permanent defences as can be constructed only at large cost, and cannot in all probability be completed for a long period of time.

My principal reason for requesting the attention of his Royal Highness and the Committee to this part of the subject is, because I consider that much importance attaches to recent experience of the nature of iron-cased ships, not only as exemplified in the French ship 'La Gloire,' but also in connection with many other details demonstrating the possibility of adopting moveable ships of considerable power in preference to stationary forts for the defence of Spithead and other anchorages of similar character.

In the present state of Europe, it is impossible to predict within what period of time Great Britain may be called upon to put forth all the resources of the country in a struggle affecting her most vital interests; and in a financial point of view it becomes important to consider not only the means which upon mature reflection may be regarded as best adapted for the permanent defence of particular localities, but to determine also by what means any defences whatever can be most readily provided in the shortest possible space of time, and at the least cost without in any manner abandoning the general principles already recommended by the Committee.

I beg leave, therefore, to state, for the information of his Royal Highness and the Committee, that I entertain no doubt whatever that it will be practicable, at a cost of about £60,000 for each ship, to convert ships of the line which are now available into iron-cased ships, with steam power capable of propelling them at a speed of from 7 to 8 knots, and with an armament of thirty guns of the heaviest and most improved description on batteries at a height of about 6 feet above water. I conceive that by prompt measures such ships might be completely equipped for service at Spithead, or in the mouth of the Thames, in a period not exceeding from fifteen to eighteen months. I imagine that it will not be desirable that they should be fitted for permanent service at sea, but that they should be so adapted as to render it inexpedient that they should be detached to a distance, and therefore that they should be constantly available for local purposes. I would suggest for especial consideration, that six such ships, stationed permanently within the Isle of Wight, would be calculated in the course of the summer of 1862 to afford much more effectual defence than is at all likely to be prepared by progress in the construction of any of the permanent forts upon shoal ground which have been suggested and recommended. I may add further, that if it should be thought expedient to spare for this purpose ships of the line already afloat, and which have been already fitted with engines, and to convert them as proposed, the cost of each ship would be reduced by the sum of about £20,000, and the expense of each battery would not greatly exceed a total of £40,000 or £45,000.

Taking into account, therefore, all the expense and all the difficulty which must necessarily attend the construction of batteries upon the shoals at Spithead, and looking also to the contingency that stationary batteries alone might not be sufficient to prevent the passage of iron-cased ships, and would imperfectly defend the entrances to Spithead against ships so protected, I am of opinion that any immediate outlay of money to be expended in the course of the ensuing financial year would be more profitably employed upon the equipment for purely defensive purposes of ships of this description; and it might be proper that the attention of the Secretary of State for War should be called to the subject, in order that reports, if necessary, from the Comptroller of the Navy may be called for without loss of time.

I am, &c.,
(Signed) R. S. DUNDAS,
Vice-Admiral.

To Major W. F. D. Jervois, R.E.,
&c. &c. &c.

LETTER.

MY LORD, 32, *Abingdon Street, 26th February,* 1861.

1. IMMEDIATELY upon receipt of your Lordship's letter of the 18th instant, we proceeded to consider the communication of Vice-Admiral Sir R. S. Dundas, dated the 8th instant, addressed to the Defence Committee, suggesting certain modifications of the measures recommended by us for the defence of the royal dockyards and arsenals in our Report of the 7th February, 1860.

2. The proposals of the Vice-Admiral may be stated as follows:—

1st. That, owing to the recent experience of the nature of iron-cased ships, vessels of that description may, to a considerable extent, be substituted for the stationary forts proposed for the defence of Spithead and other anchorages of similar character.

2nd. That, taking into account "all the expense and all the difficulty which must necessarily attend the construction of batteries upon the shoals at Spithead, and looking also to the contingency that stationary batteries alone might not be sufficient to prevent the passage of iron-cased ships, and would imperfectly defend the entrances to Spithead against ships so protected, that any immediate outlay of money to be expended in the course of the ensuing financial year would be more profitably employed upon the equipment, for purely defensive purposes, of ships of this description."

3rd. He suggests that, considering the short time in which this country may be called upon to put forth all her resources, it is desirable to determine by what means any defences whatever can be most readily provided in the shortest possible space of time, and at the least cost, without in any way abandoning the general principles already recommended, and that a speedy and economical mode of attaining this object would be afforded by converting certain steam and sailing ships of the line into iron-cased steam vessels, capable of being propelled at a speed of from 7 to 8 knots.

3. Before entering into a general discussion on the subject, we beg leave to reply to each of these propositions as follows:—

1st. That when, last year, we prepared our Report, we were then fully alive to the fact that iron-plated vessels would in future be extensively used for purposes of war, and this fact was carefully weighed by us in all the conclusions we then arrived at. We submit that since that time no experience has been gained which should induce us to alter the opinion we then expressed as to the comparative value of fixed and floating defences.

2nd. With regard to the second proposition, the additional information obtained during the last twelve months has convinced us that there is no practical difficulty in the construction of the forts at Spithead, and that the expense will not be in excess of the sum stated in our Report; further, that, taking all circumstances into consideration, the relative cost of forts and floating batteries is so much in favour of the former as to induce us to adhere to the opinions we then expressed, the more especially as we are convinced, for reasons to be given hereafter, that the forts will, in conjunction with a small auxiliary force of floating defences, effectually answer the purposes for which they were designed, whilst we do not consider that any amount of floating defences, the presence of which can reasonably be calculated upon, would effect the required object.

We cannot therefore concur in the suggestion that the construction of these forts should be postponed; on the contrary, considering that it may take three years to complete them, it appears to us that the works cannot be too soon commenced, or prosecuted with too great vigour.

3rd. As regards the third proposition, we have to remark, that whatever may be the advantages of the course proposed by Vice-Admiral Sir R. S. Dundas in respect to time and relative economy, the iron plating of certain line-of-battle ships will not give the class of vessels that is best adapted to the service which we have in view. Their great draught of water will materially limit their power of manœuvring in the shoal waters of Spithead, the Solent, and the mouth of the Thames; their speed also, if it be only 7 to 8 knots, will be insufficient. Departmental reasons, of which we are not in a position to judge, may make it expedient, as a measure of immediate defence, to plate some of the existing wooden vessels with iron; but it is our duty to point out that the class of vessels for which we recommended an expenditure of 1,000,000*l.* in our Report dated 7th February 1860 (pars. 35 and 37), is in every respect preferable as a permanent auxiliary for harbour defence.

4. We will now proceed to discuss more in detail the principles involved in the questions raised by the Vice-Admiral; and as those principles are, in a certain degree, in accordance with the views stated more at length in a pamphlet lately published by Captain Coles, R.N., which your Lordship has at the same time referred for our consideration, it will be convenient to take the pamphlet as the basis on which to ground our observations, although much that it contains has no relation to the views expressed by Sir R. Dundas. By this mode of proceeding we shall be enabled to discuss the whole question without unnecessary repetition.

5. It appears to be the object of the writer of the pamphlet to propose, that, for the purpose of protecting our dockyards from the attack of an enemy, a moveable force of iron-cased steam-ships should be substituted for the advanced works of fortification which are recommended in the Report on National Defences, these ships to be distributed at the different ports on the south coast of England between the entrance to the Thames and Plymouth. The number stated as necessary for this system of defence is 20, with the addition of 10 small steam tenders, telegraphic communication being established between the ports at which these vessels are stationed, in order that they may be concentrated on the point attacked.

6. We have stated so fully in the first three paragraphs of our Report of the 7th February last the reasons why we could not rely on naval means alone for the defence of our dockyards and arsenals, that it is scarcely necessary that we should do more than refer to them here, as there is no point in the pamphlet bearing on the subject which was not fully discussed in that Report. After the most careful perusal of Captain Coles's pamphlet, we can find in it nothing to induce us to alter the views we then expressed.

7. We found on calculation that the expense of this system would, if it were developed to such an extent as to insure efficiency, be so enormous that we could not recommend it for adoption, even if we had thought it otherwise applicable; and we are convinced that the proposal to devote so large a protion of our naval resources to a special purpose, as the writer of the pamphlet suggests, so far from increasing our security, would tend to weaken our strength by dividing our means of resistance. As the flotilla could not, from its very special nature, act with or assist the fleet, it must either be in itself so powerful as to be able to compete with any force that may be brought against it, or it must depend upon the sea-going fleet for its protection.

8. Even if we assume our naval resources to be at any time equal to those of an enemy, it must be borne in mind that the introduction of steam, on the ocean, gives to a hostile fleet a power of making feints to an extent not possessed by an army on land, and either the defending fleet or flotilla must be kept concentrated on a central point, in which case the distant ports on either flank are exposed to bombardment for a whole day at least before any succour can be afforded; or if distributed in detachments of a few vessels at each point to be protected, these

are liable to be overpowered at any moment, or to be called off by false alarms to some point supposed to be threatened.

It need scarcely be pointed out that simultaneous attacks on different points would effectually distract the operations of the defenders, rendering them liable to be overpowered in detail: for instance, a feigned attack on Plymouth would at once set the whole force in motion in that direction, while the real attacking force might pass through the Straits of Dover, capture the squadron advancing from the Downs, and proceed unmolested to Sheerness and the Thames, where they would be at liberty for a considerable time to continue their operations without opposition.

It is hardly necessary to insist more on this point; it is so obvious that there are many modes in which feints could be made, which would entirely upset any previously-prepared plans for the co-operation of the several portions of the defensive force.

9. Captain Coles, in his pamphlet, appears to think that the improvements in ordnance effected in the course of the last few years, combined with the introduction of steam, electric telegraphs, and iron-plated vessels, will cause as great a revolution in warfare as the invention of gunpowder; but these improvements have been in degree rather than in kind. The piece of rifled ordnance, for instance, is virtually the same instrument, but with greatly increased power; the principles of tactics in naval warfare with the aid of steam are virtually the same as those employed with the banked galleys of the middle ages; and iron armour is not an invention to change the system of warfare, but only a necessary protection against the improved missiles which tend to place the belligerents on nearly the same footing as before. In short, steam, electric telegraphs, and railways should be treated as accessories, but they should not be depended upon as the main elements of any comprehensive system of defence.

10. Assuming, then, that it would be unwise to trust to a moveable force of steam-ships for the defence of the dockyards, we will consider whether it would be desirable to depend solely on a stationary squadron of iron-cased steam-ships at each port, instead of the combined system of forts and ships which is recommended in the Report on National Defences.

11. It is obvious that if ships are to be the sole defence, a force must be stationed permanently at each port equal to any that may probably be brought against it in the absence of the fleet; an inferior force would evidently be no defence whatever; these vessels must be to a considerable extent manned by seafaring men, and commanded by naval officers, who, at such a time, would be better employed on board sea-going ships; and even if such large numbers were provided, the defenders would be only placed on an equality with the attacking force. The number and force of the ships stationed at each port would be known, and the enemy would make his preparations accordingly.

It is superfluous to point out that the enormous outlay, great annual expense, and periodical reconstruction of the vessels involved in such a project, renders it incapable of being entertained.

12. We pass on, then, to consider what protection the proposed forts would afford in the absence of the fleet.

As the objections in the pamphlet now under consideration are almost entirely confined to the forts proposed for the defence at Spithead, our observations will be limited to those works.

13. As regards the general question of forts, as opposed to ships, considered under present and prospective conditions of scientific warfare, we consider, for reasons to be hereafter stated, that whenever ships must lie within a moderate distance of forts, of the description we propose, in order to effect their intended purpose, those forts will inevitably have the superiority; and that the special question of the forts on the shoals at Spithead is of a character favourable to the forts as opposed to ships. Even if the forts were to be constructed of granite, with iron embrasures, having very small openings, as originally proposed, we are still of opinion, that, considering the vulnerability of the ships' decks, and the great superiority in respect to steadiness of fire from a fixed platform, the ships could not attack the forts with any chance of success.

14. The instances given in Captain Coles's pamphlet are not to the point; indeed no experience gained from the actions of the late war, where wooden

ships were employed against such forts as were then constructed, can be considered as throwing any light on the matter now before us. We will not lengthen this Report by entering into the particulars of the instances so often referred to of Bomarsund and Kinburn, but an examination of the details from different sources will make it clear that they have no reference to the present subject of discussion. The experiment referred to respecting the Eastbourne Tower has simply no bearing on the question. Ever since the invention of gunpowder it has been known that an exposed wall of brickwork or masonry could be breached by a steady fire continued for several days; but the case is altogether different when the breaching battery is on an unsteady platform, and when the duration of the action is limited to a few hours. Besides, no comparison can be made between a brick tower with walls 7 feet thick and forts of the construction we propose.

15. The forts now designed for erection on the shoals at Spithead will be of a peculiarly formidable description, and essentially different from any works that have hitherto been built. They will each be constructed for 120 guns, in four tiers; of iron 10 inches in thickness from low-water mark, unless it is found expedient to carry the foundations of solid granite up to high-water mark. They will be armed with ordnance of the heaviest description, and of the greatest penetrating power, provided also with mortars for vertical fire. They will thus be individually in every respect invulnerable to any species of projectile, and impregnable by any force of ships that can be brought against them, or by any conceivable mode of assault. Their vertical walls, 60 feet in height, will render them inaccessible by boarding, a mode of attack suggested by the writer of the pamphlet; and the foreshore of the foundations will effectually prevent the approach of explosive vessels sufficiently close to cause damage to the works. Owing to their capability of carrying any weight of iron, these forts will possess, in their offensive and defensive properties, advantages over any floating attacking force, as the latter cannot be made equally invulnerable or carry equally heavy ordnance.[1]

16. If the whole anchorage could be commanded at moderate range by forts of this description (each of which can be constructed for about the same cost as one of the vessels proposed by Captain Coles), the question would be set at rest; but even assuming that the works we propose do not effectually command the whole anchorage, they would circumscribe the space available for the operations of an enemy, and afford perfect protection for an inferior force of our own ships in his presence. It must be borne in mind, that it is only vessels large enough to bear the weight of the heaviest defensive armour that can hope to resist the fire of the forts, and that these vessels will only constitute a part of an enemy's fleet; in fact, be the substitute for the present ships of the line.

These forts, therefore, afford a perfect security against all other descriptions of naval attacking force. Moreover, the sides of the largest ships will be so much injured by the effect of rifled ordnance, even at long ranges, that they will require extensive and tedious repairs after any conflict with forts, rendering it less probable that an enemy would risk the efficiency for a considerable period of this most valuable portion of their maritime strength for the purpose of a distant bombardment of Portsmouth dockyard.

17. In order to prevent the occupation by an enemy of that space which Captain Coles assumes is not effectively commanded by the fire from the forts, we have recommended, in paragraph 23, page 15, of our Report of 7th February, 1860, that assistance shall be rendered by a few iron-cased steam-ships, which vessels will be considered as auxiliaries for the special objects there mentioned. (See Appendix.) [Page 566.]

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[1] It is scarcely necessary that we should do more than allude to the erroneous impression under which Captain Coles seems to be labouring, to the effect that the forts at Spithead, against which all his objections are in reality directed, will cost £11,000,000. What the Commissioners recommended was, that exactly one-tenth part of this sum should be devoted to this purpose, and the sum that it was agreed upon in Parliament should be taken for these forts, and some minor land batteries, was £840,000. We have no reason to believe that this estimate will be exceeded.

18. The fact also must not be lost sight of that it would be easy in time of war to place a network of obstructions and powerful explosive machines, as contemplated in the memorandum of instructions given by us to a sub-committee of naval officers, and mentioned in the Appendix to our Report, pages 63 and 65 (see Appendix, [page 568,] in those positions over which it is assumed that the enemy could otherwise move with comparative impunity. This could be done without interfering in any important degree with the free navigation of those waters by our own ships, or encroaching too far on the anchorage ground necessary for naval and commercial purposes. We are also of opinion that the knowledge that such impediments were so placed would deter the enemy from making such a hazardous attempt for so uncertain an object as a distant bombardment, or partial destruction of our ships.

19. In the scheme of attack proposed by the writer of the pamphlet, it is arranged that the enemy's ships should pass between the forts on the shoals, and take up positions varying from 1,700 to 3,000 yards from the forts, and about 7,000 yards from the dockyard which it is his purpose to bombard. We must assume that the enemy is of so enterprising a disposition that he has not been deterred from making the attempt, notwithstanding the formidable nature of the defences, and other means provided for his destruction. We will also assume that he has passed without serious damage through the Channel, and has taken up his position for bombarding. Here he must anchor; the confined space and strength of tide will render this a necessity, in order to sustain an effective fire. A portion of the ships are so placed that they cannot see the dockyard they intend to destroy, or ascertain the effect of their shells. The whole of them will now be under the concentrated and undisturbed fire of the forts, from rifled guns of great accuracy and penetrating power, aided by the fire from the floating batteries, which will have taken up positions where they can be supported by the forts. The distance at which this fire is delivered is such that little doubt need be entertained as to the certainty of striking the attacking ships, and it should be borne in mind that projectiles from heavy rifled guns, although not possessing originally so high a velocity as heavy round shot, retain their velocity to a much more distant point; and this velocity is an accurate measure of the force of impact of a shot of a given form and weight. Some of the heavy Armstrong projectiles carry a velocity of 700 or 800 feet a second to a distance of 4,000 yards, and would be formidable even to an iron-sided vessel anywhere within that radius. It is evident that the guns for effecting the bombardment cannot be placed on the upper deck, where they would be at once silenced by the fire of the forts, and if placed between decks, the vessel must be so formed, and its ports so constructed, as to allow for the elevation of the guns to about 30°, exposing a large area for the entrance of shot and shell.

20. In addition to this destructive horizontal fire, which may be carried on with perfect steadiness and accuracy, the garrison of the forts being totally undisturbed by fire from the enemy, the mortars on each work and on the adjacent shore will be brought to bear on him, and with considerable effect. It has been ascertained that at the distance of 1,000 yards at least 15 per cent. of the shells from a 13-inch mortar may be expected to fall on the deck of a line-of-battle ship; the few that would probably strike at a longer range would be sufficient to render the position of an enemy untenable. The exact distance of each ship will have been ascertained by cross bearings, taken and signalised from the forts.

We draw attention to the effect of vertical fire for the same reason that we before alluded to explosive machines below water, for it must be borne in mind that, although the application of iron plates has rendered the sides of a vessel to a certain extent invulnerable except through the port-holes, her deck will remain as vulnerable as before, and the iron plating affords no protection to those parts which are a few feet below the water-line.

21. While the enemy is suffering from the fire thus concentrated on him, the inferior force of iron-cased ships, which has hitherto been operating at a distance under the protection of the forts, will take advantage of their power of manœuvring, and attack any weak point in the enemy's formation, overpowering each ship in succession with a superior force. In fact, the proposed forts would act as the detached works of an entrenched position on shore, not only in enabling an inferior body of men to resist the attack of a more powerful one, but

also in their capability of protecting a force to act at the right moment offensively against the enemy. The forts would have the further advantage, that in the event of the enemy being desirous of quitting position, and in a partially disabled state, he will have to encounter in his retreat all the means of defence entirely unimpaired which were prepared to oppose his entrance.

22. Although, therefore, Captain Coles might perhaps be considered as warranted in describing the central portion of the anchorage at Spithead as an area of invulnerability, on the assumption that the proposed forts were to be armed with smooth-bored ordnance, he certainly is not justified in so doing with the knowledge that 100-pounder rifled guns are already available for such purposes; and the improvements in rifled ordnance are going on so rapidly that we see no reason to doubt that much heavier guns than these will be perfected[1] before the forts are completed; indeed, we are informed that a proposition for making a 300-pounder gun has already been submitted by Sir W. Armstrong; and with the mechanical appliances which exist, we look forward to the employment in forts of guns throwing shot or shells 300 or 400 lbs. weight with such velocity and to such ranges, as shall render the roadstead at Spithead, if fortified as we proposed, perfectly secure against any vessel now built or proposed, and we do not foresee the possibility of any vessel being constructed so as to carry armour of such thickness as to protect her against the fire which could then be brought to bear upon her.

23. It is further objected that the forts on the Horse Sand and No Man's Land will afford sure marks or beacons for the passage of the enemy's ships through the Channel, enabling them to steam by them at full speed. To this we would reply that in the absence of the forts the enemy would find no difficulty in entering Spithead. He would probably proceed more slowly, which at the utmost would delay his attack for perhaps an hour, but no other advantage would be gained by their absence. It can scarcely be contemplated that we should ever be in such a position as to be compelled to remove the buoys and light-vessels which are indispensable for the secure navigation of our own ships; and so long as the Nab and Warner light-vessels remain, no other marks are required; if they were removed, the forts will not aid him by night in the most difficult part of the Channel, and the leading marks into Spithead are distinct objects on the land which cannot be removed, and will therefore always be available for him by day. In fact, without forts, beacons, or buoys, an enemy's ship would find little difficulty in finding her way into Spithead, unless in the face of an equal or superior force. His progress might be slow, but his entry would be certain.

24. To one important point we have not yet referred—the question of expense. The cost of each of the works which it has been proposed to supersede by iron-cased ships, will be about £270,000, considerably less than the cost of one ship of the 'Warrior' class, and about equal to one of the ships proposed by the writer of the pamphlet. The fort will last for centuries, and the cost for its maintenance will be insignificant; the ship will require constant repairs and periodical renewal. The fort is impregnable and invulnerable; the ship is at the mercy of two vessels of equal power.

25. We have hitherto treated the subject solely with reference to the defence of Spithead, and to the protection of Portsmouth Dockyard from bombardment; but it must be observed that the proposed forts are of the utmost importance with reference to the general scheme of defence to seaward of Portsmouth, of which that of the Isle of Wight is one of the most important parts. With the two entrances to the Solent fortified, and combined with a small force of local floating defences, the northern shores of the Isle of Wight are secure, and it only becomes

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[1] Captain Coles seems himself to contemplate the introduction of these improvements, inasmuch as he states [page 549], that he sees no reason to doubt but that in the next five years we may increase the range of our ordnance as much as we have done during the last five. Although he employs the argument only in favour of his own views, it is evident that by doubling the range of the guns of the forts, he would practically decrease their distance by one-half, and so obliterate the so-called area of invulnerability altogether.

necessary to apply some comparatively inexpensive means to defend those portions of the coast of the island between the Needles and St. Helen's to the southward. Without the proposed forts an enemy in the absence of our fleet would be free to land on the north of the Isle of Wight, if he attacked with naval means superior to the iron-cased ships which are proposed by Captain Coles. Moreover, the absence of the forts would necessitate that a large military force should be specially appropriated to the defence of the Isle of Wight, from whence it could not keep up its communication with Portsmouth, neither could reinforcements be thrown from Portsmouth into the Isle of Wight. In the general arrangements for defence it would be advisable that a great part of the garrison allotted to Portsmouth should be stationed in the Isle of Wight, ready to meet the probable first attempt of an enemy to obtain a footing on the island, and thereby to gain possession of the waters of the Solent. With Spithead and the Needles defended by forts and floating batteries this disposition could be safely made, and any portion of the force that would be required to meet an attack in other quarters could be withdrawn.

26. Again, if the defence of Spithead be reduced to the few iron-cased ships proposed, an enemy superior in naval means at the moment might throw a force on shore to the westward of the Gosport line of defences. In short, during the temporary absence of our fleet, we practically abandon the Solent to the enemy.

27. We have now noticed all the points contained in the letter of Vice-Admiral Sir R. Dundas, and alluded to those which appear to us of importance in the pamphlet by Captain Coles. As yet, however, we have not adverted to the pamphlet translated from the French, entitled "Reflections on the Navy," to which your Lordship directed our attention. We have carefully perused it, and we consider it to be a most important document, showing, as it does, not only the steadiness of purpose evinced by the French to rival this country in its naval power, but also the accurate and careful appreciation of the relative strength of the two countries, and of the means by which, in the event of a rupture with France, the power of Great Britain may most effectually be humbled. See page 22, "Reflections on the Navy."

28. Surely it is a subject of regret, that when the points of weakness of this nation are being so justly measured by its rival, and when, it appears to us, we should be perfecting our defensive system in all its departments, the question of our national security should be narrowed down to a controversy between the relative merits of ships and forts.

The object of all general plans for the defence of a country should be to bring to bear all its different powers of defence into one comprehensive system. With us iron ships and sailors are of paramount necessity; the army, including the militia and volunteers, is essential to our security, but neither the sailor nor the soldier can afford to dispense with the aid of the engineer.

29. We cannot find the views of Sir R. Dundas enunciated in the French pamphlet under our consideration. True, the author lays down at page 7, that no number or weight of batteries will prevent a fast screw-ship forcing the passage of a channel, and therefore that not only should batteries be placed at the entrance of an inlet, but also that within the channel, where the ship must stop, the most formidable engines of destruction should be collected and arranged.

This is in effect a similar statement to that made by us in paragraphs 56 and 63 of our Report, when considering the principles of some of our recommendations. (See Appendix.) [Page 568.]

30. The author, moreover, says a great deal (page 8) about the comparative facility with which a distant bombardment may now be effected, but he does not draw the conclusion that advanced works of fortification are therefore useless. On the contrary, he speaks (page 9), as we did, of floating defences being required in certain cases as auxiliaries to fixed works.

It certainly appears to us a strange argument that, because, by the introduction of iron-cased vessels, bombardment has become comparatively easy, and consequently, that iron-cased ships are required for protection, therefore, the defending vessels are to be deprived of the support of forts, and are to be put on an equality with an equal number, or on an inferiority with a greater number of a similarly equipped squadron of the enemy.

31. The author of the pamphlet alludes to our strength in naval entrenched camps at Portsmouth, Plymouth, Dover, and Portland, &c., and he clearly appreciates the value of them to us in case of war. But these places are not entrenched camps, unless they are fortified. As well might it be contended that redoubts were of no use to an army on a field of battle, and that the use of field artillery would enable us to dispense with such aid, as be said that we could afford to dispense with forts and substitute a few ships to provide for the security of those important anchorages.

32. We observe further that the views of the author are, (page 12), "that the fleet is created, kept up, organised for the object of making war." Again (page 19), "that the fleet should acquire a complete independence of action, and a free disposal of its forces for all the operations of an offensive war."

We submit that that is true not only of the French, but also of the British fleet; and it is on this principle that the recommendations of our Report of last year were based, not only with respect to the navy, but with reference to the army also.

33. Although not exactly to the present point, the principles of our recommendations are so much involved in the question now immediately referred to us, that we think it advisable, before we conclude this letter, briefly to draw attention to those principles.

We stated that our navy was our first line of defence; we drew attention to the necessity of maintaining our naval superiority, and urged strongly on the Government of the country that every means should be taken to ensure the efficiency of the fleet.

Impressed as we were with a sense of the paramount necessity of maintaining an efficient navy, the security of the dockyards and arsenals, and ports in connection therewith, appeared to us a consideration of primary importance. We therefore proposed to defend them in such a manner as to set our fleet free, to operate offensively against the enemy or defensively for the protection of our shores, and upon such a principle that, in the event of an enemy having effected a landing on our coast, (the garrisons of the places in question being composed principally of troops not forming part of the regular army), our manœuvring army could operate against the enemy upon the coast, and could be massed for the defence of the capital. See page 22 of "Reflections on the Navy."

34. If the measures we suggested be not in principle adopted, the effect would be that both the fleet and the army would be obliged to manœuvre so as to protect these places, and must consequently be more or less dispersed; fortification is simply the best method of defending them with the least possible number of men and ships. In short, the effect of fortifying our dockyards and arsenals is to provide at the smallest cost so much addition both to our regular army and our fleet. We conceive that there is a limit to the extent at which we can maintain our navy and our army, and if from the absence of standing defences, either the one or the other were compelled to defend our naval establishments, the fleet cannot concentrate for defence or for attack, or protect our interests abroad, neither can the army unite to meet the enemy at home.

35. Lastly, financial considerations may sometimes lead to great reductions both in the fleet and in the army, and when our forces are thus brought to a low ebb, and without any well-arranged system of defence, we are suddenly called upon to prepare for war, our condition will be weak in the extreme; but with the permanent works once constructed, they afford for centuries the power of defending our vital points by the partially disciplined forces which could be gathered from the population, whilst the resources of the country are in progress of organisation.

36. In answer, then, to the three questions submitted to us by your Lordship, we beg leave to reply as follows:—

1st. We adhere with the utmost confidence to the opinion we formerly expressed as to the necessity of the forts for the protection of Spithead, more especially as regards the two outer works on No Man's Land and the Horse Sand, which give protection to the anchorage as a harbour of refuge for an inferior force of our own fleet, and for merchant vessels, which the 'Spit' and 'Intermediate' forts cannot afford, owing to the depth of water near them being insufficient for anchoring purposes. These two outer defences also command more effectually the space which might be occupied for the purpose of bombardment, and would take in reverse any ships which had succeeded in forcing the passage.

The work on the Sturbridge is, in our opinion, only second in importance to the two first mentioned. It completes the circle of defences which will afford a concentrated fire on the anchorage, provides a second line against an enemy attempting the passage of the Solent, and gives shelter to floating defences which might have been obliged to retire before a superior force either from the outer entrance to Spithead, or from the defence of the passage of the Needles.

It appears that Her Majesty's Government propose to suppress the two minor forts on the Spit and the Horse Sand. We, therefore, think it advisable especially to draw attention to the importance of the former work, as from its central position it would afford a raking fire on the channel between No Man's Land and the Horse Sand, take in reverse the passage between the Sturbridge and Gilkicker, and give additional protection to the entrance to Portsmouth Harbour. If, however, it be finally decided that this work should not be constructed, we recommend, in order to preserve as far as possible the equilibrium of defence, that the batteries on either side of Southsea Castle should be materially strengthened.

2nd. We consider the mixed scheme of defence by forts and auxiliary iron-cased vessels to be the only practicable mode of effecting the object in view.

3rd. We are of opinion that no time should be lost in commencing the forts, and in constructing as many iron-cased vessels as are essentially necessary for the above purpose.

We have, &c.,

(Signed) HARRY D. JONES, Lieutenant-General.
F. ABBOTT, Major-General.
GEO. ELLIOT, Rear-Admiral.
A. COOPER KEY, Captain, R.N.
J. H. LEFROY, Colonel Royal Artillery.
JAS. FERGUSSON.

Wm. F. Drummond Jervois, Lieut.-Col. R.E.,
and Assist. I. G. F. Secretary.

Major-General D. Cameron having been appointed to the chief command in New Zealand, is now absent from England.

APPENDIX.

EXTRACTS from the Report of the Royal Commission on National Defences, dated 7th February, 1860, relative to the Employment of Iron-cased Floating Batteries.

Floating Batteries.

21. YOUR Commissioners have taken into consideration the expediency of constructing floating batteries, to aid the permanent fortifications in the defence of the more important positions. Such a mode of defence has been almost invariably referred to in the numerous schemes that have been proposed from time to time, for the security of naval ports and arsenals, and has given rise to many conflicting opinions as to the circumstances under which they should be adopted, and the best method of constructing them. With a view to obtaining a solution of this question, and also to ascertain the most effective description of boom for obstructing the entrance to a harbour, we requested permission to appoint a committee of naval officers, in whose experience and judgment we could place reliance, for the purpose of fully inquiring into and reporting on these subjects.

This committee was formed under the presidency of Rear-Admiral Sir Thomas Maitland; and after careful inquiry and deliberation, in which they received assistance from several eminent shipbuilders, they transmitted their Report, which will be found in the Appendix. (Appendix 1.) [Page 568.]

Stationary Floating Batteries.

22. The first point to which they turned their attention, was to determine the best mode of construction for a floating battery without motive power; it was supposed that

such a vessel might be placed in an advantageous position at a time of expected attack, and that the guns might be worked by landsmen trained for that special purpose.

The committee have devised a battery of this description, combining the properties of a vessel and a raft, and possessing the various requisite qualities, more especially those of steadiness and light draught of water. The expense of such a battery would be considerably greater than that of a masonry work bearing the same armament, and would be by no means so efficient on many grounds. Stationary floating batteries would not only be more expensive in the first instance, but would involve a considerable annual outlay for maintenance, and would require periodical renewal at certain intervals: they are liable to be sunk by the concentrated fire of or collision with large ships, the approach of which cannot be guarded against at high water, owing to the great rise of tide on the coast of England; they cannot, under any circumstances, afford a perfectly steady platform for accurate fire, such as is now more than ever indispensable with rifled ordnance; and they have not that advantage which is possessed by a casemated work, of affording good barrack accommodation.

Your Commissioners therefore do not recommend the adoption of stationary floating batteries of this description, under any circumstances.

Moveable Floating Batteries.

23. The Committee have, however, also brought to our notice a far more perfect description of floating battery, which they conceive would be highly efficient for defensive purposes. It may be described as a powerful iron-sided steam-vessel, capable alike of maintaining a fixed station or manœuvring in a general engagement, of sufficient size to afford a steady platform for working the guns, yet not so large as to be unmanageable in narrow waters; mounting from 12 to 20 guns, having a speed of from 8 to 10 knots, and of as light a draught of water as is consistent with other good qualities. Vessels similar in dimensions, armament, and general description to that which they have recommended would be, in some instances, most serviceable as auxiliaries to the permanent fortifications for the defence of harbours and inner waters. They would be free from many of the objections to which the stationary floating battery is liable, and would possess far greater advantages.

Such vessels would be of great value during an attack, from their capability of moving to the assistance of any of the forts requiring support, of concentrating their force on an inferior portion of the enemy's fleet, or of preventing the escape of disabled ships, and destroying those that had run aground; they would be serviceable also in annoying the enemy while attempting to buoy the channel; the vessels themselves being enabled to avoid an attack of a superior force, by retreating into shoal water, to which the sea-going vessels of the enemy would be prevented from following them, owing to their greater draught of water.

Your Commissioners therefore recommend that measures should be concerted for the construction of vessels of this description for the special purpose of harbour defence, to be used in such positions as shall be hereafter specified. They should be divested of all qualities that are not necessary for this kind of service, in order to reduce the expense of building, and to prevent them from being detached on other duties. The iron-plated floating batteries already existing would co-operate with them, and would perform in a lesser degree many of the services required for harbour defence.

Floating batteries are proposed as part of the permanent defence, irrespective of any number of gun-boats which may happen to be present. We do not consider these latter at all adapted to cope alone with the class of vessels which will certainly be employed in future naval attacks.

Needles and Spithead.

67. Your Commissioners consider that a few vessels of that description which they have recommended for harbour defence, would form a valuable auxiliary to whatever portion of the sea defences may be threatened with attack; they would effectually prevent such a partial bombardment of the dockyard as might be attempted by the small vessels of the enemy, while the larger ships were engaged with the batteries; and they would, at all times, be able to retreat under the protection of the batteries when in danger of being overpowered by a superior force.

Thames and Medway.

136. We consider, however, that the force of moveable floating batteries, which has been previously referred to, should be stationed at Sheerness, for the purpose of aiding in the

defence of the Thames and Medway, as well as to guard against any desultory attacks that might be attempted by a small force of the enemy, with the object of bombarding Sheerness dockyard. It is considered that such a means of defence would materially assist in checking the advance of an enemy in whatever force, and hamper him considerably in any operations he might undertake in this vicinity.

EXTRACTS from the Report of the Royal Commission on National Defences, dated 7th February, 1860, referred to in this Report (page 564).

56. WE are, however, convinced that no practicable amount of fire from batteries can be depended upon to stop the passage of steam ships, if the channel be sufficiently clear to allow of their proceeding at great speed.

On the other hand, there is no reasonable probability of a fleet attempting such a passage, unless it can, by continuing its course, arrive at a space where it would be comparatively unmolested, and be free to carry out some object of importance, such as the destruction of a fleet or of a dockyard.

63. As before observed, we do not consider that any amount of fire which it would be practicable to bring to bear upon a channel such as this would prevent steamers from running through, provided there were any sufficient object to be attained, and that the officers in command were determined on risking the loss which they would probably sustain in the attempt.

In the present instance, the principal object of an enemy would be either the destruction of our ships at Spithead, or an attack upon the dockyard; but these attempts would be impracticable if the works above proposed were constructed at Spithead; and we are therefore led to consider whether any other inducement would remain for an enemy to risk the passage of the Needles.

EXTRACT from the Report of the Sub-Committee of Naval Officers printed in the Appendix to our Report of 7th February, 1860.

Submarine Obstructions.

THE Committee have not been able to ascertain more simple or more efficient forms of submarine construction than—

1. Sunken vessels laden with stone or other heavy substance, where the depth at high water does not exceed 6 or 7 fathoms. Vessels may also be fitted so as to be speedily filled and pumped out, for being raised and sunk.
2. Piles, where the depth of water and nature of the bottom will admit of this method. They should be sloped outward, and strongly trussed together, with the upper ends armed with iron.
3. Explosive machines in narrow passages, which, under certain circumstances, may be most advantageously employed.

The plans to which reference has been made accompany the Report.

(Signed) T. MAITLAND, Rear-Admiral.
E. GARDINER FISHBOURNE, Captain, R.N.
ARTHUR A. COCHRANE, Captain, R.N.
M. S. NOLLOTH, Captain, R.N.
COWPER P. COLES, Captain, R.N.

MEMORANDUM on the Defences for the Eastern Entrance of Spithead, by General Sir JOHN BURGOYNE, Bart., G.C.B., Inspector-General of Fortifications.

THE eastern entrance to Spithead is by too wide and open a channel to receive protection from defences on the shore; and it has been proposed, therefore, to establish batteries on the projecting shoals that are on each side. These batteries will be thus brought within about 2,400 yards of each other, and it is proposed to add to them one or two additional works within the roadstead.

As the sites for these constructions are in a depth of water of from 12 to 20 feet at low tide, the cost of their foundations up to high-water level must be very considerable, and they can hardly be completed in less than three years. On these grounds, added to doubts expressed by some officers of their ultimate utility (not relative, but positive utility, even when established), it has been suggested by many that the proposition should be abandoned in favour of floating defences, to be applied on various systems; some proposing that each vessel should be provided with full steam power, to constitute a regular moveable manœuvring force; and others, that they should be converted from old men-of-war to the purpose of floating batteries for the locality exclusively, and with very small moving steam power; but all of them require that the defensive vessels should be iron-sided, to resist shot and shells. It may be well, however, to commence with the question of the inutility of the forts even when constructed; because if that be established, it would be needless to pursue the matter further.

The argument is, that the attack being by fast steamers, the passage by the forts would be so rapid that they would be so short a time exposed, and the fire from the batteries so wanting in precision, that the ships would scarcely be hit, or, at all events, by a very few random shot; and as they would be iron-sided, that the shot that did strike them would not penetrate. It is more than questionable, however, how far these objections are valid.

The movement of a steamer at 10 or 12 knots certainly presents a very unfavourable target for any steady practice upon it, but as they must advance in a direction nearly end on to the battery, their great length will afford a considerable latitude for the chance of shot and shells falling on the decks, which for the first 2,000 or 3,000 yards of their course under fire will be far more exposed than the sides, in consequence of the curve of the trajectory of a shot at long ranges. And as regards this practice, the lateral deviation of the shot is small at any range; the only difficulty is in the length of range or accuracy of elevation according to distance; on the decks, even one or two heavy shells taking effect would probably be attended with serious consequences.

When the vessel is abreast of the battery, the practice may be so certain that no shot can hardly fail to hit her, for she will not run her whole length in the time of the shot's flight from the battery; therefore the guns being directed across the channel, and fired when her bow is in the line of fire, she must be hit somewhere. After that again, in receding, she will be exposed to the same elevated chance shot and shells as in advancing, and, as she must come upon the forts in succession, will be advancing upon those within as she is retiring from those that are outermost; whatever, then, might be the difficulty of steady practice against such moving masses, the chances of escape from the showers of projectiles fired towards her, even from distances that must be judged at discretion, will be but small, and this will be quite as fully or perhaps more the case, if the ships be in numbers, as if single.

So much for her not being hit, on account of her speed.

We have then to consider the assumed power of the iron sides to resist shot.

This, no doubt, has been shown to a certain extent; scattered shot of the ordinary character, even from heavy calibres, from rifled as well as the old kind, and at short ranges, have failed to penetrate; but few of them that hit did not make an impression, to the extent of cracking the iron or the timber within, driving in bolts, and altogether tending to disintegrate the construction of the sides. This is more particularly the case if the shot strike upon a joint or edge; and there is no doubt that a number of shots, or two or three, happening to strike at all near the same place, would effect considerably injury. But this is not all; for Whitworth, with prepared hardened flat-headed shot, at 400 yards range, completely pierced one of these sides; and though it has been arbitrarily assumed that at 1,000 yards the same effect would not be produced, it has never been proved what amount of injury they would do at that, or even greater ranges, the reduction in the velocity of the shot from rifled guns at increased ranges being far less rapid than with the smooth bore.

It may be objected that such peculiarly prepared missiles as these last would be very costly, but they would be rarely employed, not for habitual service, and not even for practice after the knowledge of their effect were once proved; but they would be reserved for distinct application from batteries, solely when firing at effective ranges against the iron side of an enemy's ship. The expenditure therefore would be trifling.

Then it is held as a triumph that, at all events, there is no doubt of the iron plates resisting shells perfectly; but there will be no difficulty in giving the rear end of this penetrating kind of heavy shot a receptacle for a charge of powder and fuze, that will give it at least some amount of explosive power; and that, however comparatively small, may be very dangerous in a ship; thus combining the power of shot and shell. In addition to these effects, to which the solid coating of iron is liable, there is an amount of opening of the ports of every armed ship, which, in the aggregate, presents a considerable space for the entrance of shot or shells of the smallest force, and without any impediment whatever; to which may be added the edges round them for about six inches are liable to very great injury; so that altogether, although they would clearly require much more battering than a timber ship, which would give them an enormous advantage over the latter in action, it is a very bold expression to call these sides (as they have hitherto been denominated) invulnerable.

The assumed inutility of these forts is entirely founded upon the said inefficiency of their shot against the iron sides; but it will not be disputed, that against timber sides, at least their large shells might be fatal; and as the iron application is most costly, such ships might not be forthcoming, and can hardly be employed in great force, it is evidently a great advantage gained to prevent the timber ships from co-operating, or being employed altogether in the attack.

A further objection to the forts is, that they would afford marks to guide the enemy in, through the shoals; but this disadvantage can scarcely be considered great since it would only afford a guide between the first points met, where the passage is in mid-channel, and upwards of 2,000 yards wide, and through which bearings can be taken to other landmarks.

It is also said against them that they are not moveable, not generally available anywhere as first-class floating defences may be; but they are for a fixed object, always at their post; and it may be even in their favour that they cannot be removed from it; if they cannot close with an enemy, on the other hand, the enemy must close with them to gain his object.

In fact, this argument is very similar to what was partially held of old, but very generally exploded since, of the impolicy of fortresses on the land frontiers of states, on the assumption of how much better it would be to trust to the armies, which were moveable and available everywhere. But many instances may be shown where armies were not and could not be competent to the defence of a country at the time, which has been saved by its fortresses; and, in modern times, there have been no greater advocates for fortresses than the most eminent generals, such as Napoleon and Wellington.

We will now bring forward another defensive property of these forts, namely, that they would enable us to maintain in full force a system of floating mines, and other obstructions of the most dangerous character to the assailants, and to cover and protect the smaller active steamers that would watch the movements of the enemy by night, and counteract any of his boating enterprises, such as it is presumed will henceforth take the duties of the rowing guard.

As a last illustration of the utility of the forts, let us assume them to be made, say three in number only, that is, one on the Horse Shoe, another on No Man's Land at the entrance, and the third on the Sturbridge Shoal in the interior, and it is not easy to understand what the enemy is to do, should he succeed in forcing his way in.

It is said that spaces are to be found, and so they are, by scale and compass, on the chart, where he can lay in many positions within the long range of bombarding distance of the dockyard, and not be within from 1,200 to 1,700 yards from any fort or land battery, that is, not within the magical 1,000 yards, beyond which he is to be deemed invulnerable, that of these positions he would take advantage, and from thence would destroy the dockyard and its contents, and then retire: that is, that he would be for a few hours calmly carrying on his practice, while his decks would be exposed all the time to showers of projectiles from batteries and forts in all directions—shot and shells of the heaviest calibre, molten iron, rockets, &c. We cannot suppose such a miracle as a single vessel escaping annihilation under such circumstances.

We think that the utility of these forts, or something to replace them, in addition to anything that can be applied on the mainland or on the Isle of Wight, has thus been shown to be necessary; and we now come to the relative advantages of the proposed substitute of floating defences, that is, powerful iron-sided men-of-war, either as regular manœuvring steamers, or to be moored as floating batteries.

The principal objections to this system, by comparison with the forts, are—

1st. Their great expense. The cost of the iron-clad steamers is well known to be very great, quite as great as that of the forts in first cost, even in this very unfavourable locality (as regards expense) for the latter; and that expense is incurred for a very perishable article; and which during its existence, will require constant outlay in maintenance, while the other may be expected to last for ages.

2nd. That each vessel is under liability of being burned, or sunk, or wrecked, or to have steam engines, boilers, or other gear damaged or out of order; to none of which are the forts liable.

3rd. That they will take away from the available resources of the sea-going manœuvring fleets. This is self-evident; they will be composed of the same articles, and cannot be at two places at once. Their far more essential and their primary application will be with the fleets, to endeavour to maintain the maritime superiority in the Channel, and to protect the necessary maritime influence in distant seas. This will afford full employment to all the naval means we can possibly produce; the more, then, they can be relieved of any other charge the better; and it has been shown how well the forts may perform that part, not but what any men-of-war, large or small, that may be at Portsmouth at the time of attack, may render valuable co-operation.

If these floating defences are to be constantly maintained at each station, of course they will be by so much abstracted from the manœuvring fleets; if not, they may not be forthcoming when the protection is needed; and they must be in sufficient force, too, at each port, for with an enemy in command of the Channel, which he must be at the time, to undertake such an enterprise, he would effectually prevent reinforcements being sent from ports not attacked to one that is.

By the proposed system of floating defences, not intended to be applicable to manœuvring or to go to sea, they would be, in fact, moored batteries or floating forts, with all the disadvantages of both kinds, and absorb large means from the naval establishments besides.

There may be an impression that they might be fitted up from the hulls of inferior men-of-war, and consequently inexpensive; but still, allowing for maintenance, repairs, necessary renewals, not by any means to the degree that would be supposed; and it would be a measure of expedients, that is, a provision of an inferior article, to attempt to save an immediate outlay.

In considering the contests between ships, however well protected, and shore batteries, there are enormous advantages attainable by the latter; they may be, for instance, scattered by ones or twos—they may be on heights—or they may act by a flanking and not front fire—in all which cases the fire from the vessels must be very inefficient.

The errors in the fire from a stationary platform at a moving target will be far less than from a platform with the slightest movement at a stationary target.

They can be also covered by an iron front far more capable of resistance to shot than anything yet found practicable for vessels.

The assertion that the protection given to ships will no doubt be greatly improved—that their sides may possibly be much strengthened—that means may be found for covering their decks—and that their sides may be at an angle to turn the shot instead of vertical, may, perhaps, ultimately turn out true; but much time must elapse before all these things are established; and, after all, the argument will tell both ways, for great improvements are in progress in heavy ordnance and the means of overcoming such obstacles; and to judge of the future by the past, the powers of destruction will always keep in advance of those of construction.

March, 1861. J. F. BURGOYNE.

LETTER of Sir W. G. ARMSTRONG to the Under Secretary of State for War.

SIR, *Newcastle-upon-Tyne*, *April* 29, 1861.

WITH reference to your confidential letter of the 18th instant, enclosing the Report of the Royal Commissioners on National Defences, I have the honour to remark that my first impression on reading that very able document was, that we were not yet in possession of sufficient data to enable us to judge of the relative merits of forts and floating batteries; but a more careful consideration of the subject leads me to concur in the opinion expressed by the Commissioners.

Although we are as yet very imperfectly acquainted with the power of artillery against iron-plated ships, yet I think we know sufficient to conclude that, taking guns such as we now possess, and iron-clad ships such as are now constructed, it would not be practicable for hostile ships to take up the positions suggested by Captain Coles, and deliberately bombard the dockyard, regardless of the fire from the forts. I conceive, therefore, that the forts would be a complete protection against iron-cased ships, such as are now in existence, or in course of construction; and although it may be expected that great improvements will be made in the resisting powers of ships, yet, on the other hand, we may anticipate that those improvements will be fully counterpoised by the production of more powerful guns, so that the relative advantages of forts and ships will probably remain much as at present.

It is only by using long guns, at extreme angles of elevation, that the dockyard could be reached from the positions in question; and no iron-clad ships, as now constructed, would admit of such guns being so used except upon the upper deck, where they would be unprotected against the fire from the forts. Special modes of construction, such as that, for example, proposed by Captain Coles, may eventually be adopted, to afford protection to the guns when thus used at high angles; but the object will only be effected by increasing the difficulty of constructing and navigating the vessels.

If the Commissioners be correct in assuming that the bombarding ships would have to anchor, in order to sustain an effective fire, then it is to be observed that having thus lost the advantage of mobility, and having their attention entirely taken up with the bombardment, and probably unable even to reply to the fire of the forts, they would be assailable at extreme disadvantage by the iron-cased vessels which the Commissioners propose should be provided as auxiliaries to the forts. Even gun-boats could be used with effect against iron-plated ships thus occupied and at anchor; but perhaps the most formidable instruments which could be brought against ships in such a position would be iron-cased steam rams, which could be so directed as to strike an enemy's ships unable to evade the blow, precisely at the point where the crushing effect of the ram would be the most fatal.

With reference, also, to the fire of the forts, I would observe that the proportion of projectiles striking the sides of the vessel, which would enter the ports, is by no means inconsiderable, and very few shells of the present construction bursting between decks would suffice to paralyse the crew; while those which took effect on the opposite side would speedily strip off the armour and render the vessel defenceless, if subjected to a cross fire.

I have, &c.,
(Signed) W. G. **Armstrong.**

The Under Secretary of State,
War Office.

XIII.—Spithead Forts.—Reply to the Royal Commissioners' Second Report on "Our National Defences." By Captain Cowper Phipps Coles, R.N. 1861.

Although it was a cause of great regret with me that on application to Colonel Jervois, the Secretary to the Defence Commission, I was refused a copy of the Report of the Commissioners for National Defences—such Report being virtually a reply to objections urged in a pamphlet by me upon a question of the deepest public importance—I have lost no time in considering the fresh views of the Commissioners. In doing this, I cannot avoid saying that I am greatly at issue with them when they state, in paragraph 28, [page 564,] "Surely it is a subject of regret, that when the points of weakness of this nation are being so justly measured by its rival, and when, it appears to us, we should be perfecting our defensive system in all its departments, the question of our national security should be narrowed down to a controversy between the relative merits of ships and forts." I submit it is because our strength is so justly scanned, that it behoves us not to rush into fruitless expenditure. Still, regarding expense as what it really is in such a matter, of very secondary importance, let us be sure that the great object we have in view is really effected; and this can only be done by using that free discussion and healthy ventilation by which truth is eliminated and right secured.

First, I desire to say broadly, that the twenty iron-cased ships and ten small ones, proposed in my former work, were for the defence of the coast, and not for that of Portsmouth alone. The question now at issue is, whether the proposed sea-forts, in conjunction with a small auxiliary floating force and other adjuncts, will protect the roadstead and dockyard of Portsmouth; or whether in lieu of these forts, at no greater expense, iron ships, as proposed by Admiral Sir Richard S. Dundas, may be substituted; and putting us thereby in possession of an infinitely superior force, able to effect that which the forts might fail to do.

The letter of the Admiral clearly shows and recommends that available ships of the line could be fitted with engines and converted into iron-cased ships, for this local purpose, carrying thirty of the heaviest guns, at £60,000 per vessel, thus giving *fourteen* of these vessels for the sum estimated for the *three* forts (viz., £840,000), or if it should be expedient to take vessels already fitted with engines, they could be converted for £40,000 or £45,000 per ship, giving 20 or 19·6 vessels for the same cost as the forts. The Admiral concludes his letter with the following remark :—" Taking into account, therefore, all the expense and all the difficulty which must necessarily attend the construction of batteries upon the shoals at Spithead, and looking also to the contingency that stationary batteries alone might not be sufficient to prevent the passage of iron-cased ships, and would imperfectly defend the entrance of Spithead against vessels so protected, I am of opinion that any immediate outlay of money to be expended in the course of the ensuing financial year would be more profitably employed upon the equipment for purely defensive purposes of ships of this description, and it might be proper that the attention of the Secretary of War should be called to the subject in order that reports if necessary from the Comptroller of the Navy may be called for without loss of time."

To this momentous question, I submit the Commissioners have given no satisfactory reply, but have preferred to debate in detail matters of minor importance, always liable to modification, and necessarily dependent upon extraneous circumstances.

They dispose of the Admiral's offer in one line, by saying that they prefer their own vessels; an easy but somewhat arbitrary mode of reasoning, which can hardly be deemed satisfactory or conclusive, when the whole system upon which their preference is based may be proved utterly defective.

They object to the class of vessels proposed by the Admiral, 1st, "on account of their great draught of water." But Spithead contains a *very spacious area, with never less than* 30 *feet at low-water spring tides*, and it is well known that in Stokes's Bay our largest ships try, and also turn at, their greatest speed; so far, then, this objection cannot hold good. Besides, it must be remembered that 'La Gloire,' and such like vessels, against which all these defences are proposed, draw about the same water as these identical ships. And mark the contradiction offered by the Commissioners in their two Reports, with reference to this great roadstead. In the first it is termed by them a "*spacious*"—in the second, it dwindles down to a "*confined space.*" Again, they object "that their speed, if it do not exceed seven or eight knots, will be insufficient." Great speed no doubt is an advantage, and may be of the utmost importance in the open sea; but as these vessels are recommended solely for Spithead and the Solent, surely the proposed speed is sufficient for manœuvring in an action confined to this space. To obtain great speed involves great length of vessel, and the greater that length the slower the vessel is in manœuvring and turning. I therefore submit that those old liners, which are one-third less in length than vessels now building, would be well adapted to the defence of Spithead.

Moreover, the Commissioners, in their first instructions to the Committee of Naval Officers, say, "the floating batteries should be without motive power;" and after it was represented by us how necessary it was to have motive power, we with some difficulty obtained a memorandum to the following effect :—"It is also desirable that the Committee should consider, in the larger description of battery it will be desirable to give them self-motive power, to enable them to change their position slowly when required; but as these batteries are intended *solely* for harbour defences, sea-going qualities are not required."

Upon which the naval officers pointed out to the Commissioners that the amount of speed was a mere matter of first outlay, with a corresponding small expense, as will be seen by referring to their Report, page 64, part iii.[1] Thus now the Commissioners condemn vessels with seven or eight knots' speed, although formerly they considered their being able to change their position *slowly* sufficient.

The Commissioners state (paragraph 7), [page 559,] "As the flotilla could not, from its very special nature, act with or assist the fleet, it must either be in itself so powerful as to be able to compete with any force that may be brought against it, or it must depend upon the sea-going fleet for its protection." But if we remember, that for the same sum of money estimated for the building of these *three* forts at Spithead we shall, in adopting the views of the Admiral, obtain *fourteen* iron-cased ships, in addition to the auxiliary force conceded by the Commissioners, he indeed must be a bold enemy who would venture to grapple with such an armament, in addition to the existing land batteries, in our own waters, where, if worsted, he would, in retreat, be liable to meet with, and be utterly destroyed by, our flank ships summoned by telegraph from other ports to the scene of action.

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[1] Had the instructions given to the Committee of Naval Officers been published in the same manner as those given to the Commissioners, it would have thrown a different light on the former's Report.

Why these formidable iron-cased ships should not *move* to the assistance of the fleet when in the vicinity of our own port, I know not. But it is evident the *forts* cannot do so, and must be powerless beyond the range of their guns.

In paragraph 8, (page 560,) it is stated, "It need scarcely be pointed out that simultaneous attacks on different points would effectually distract the operations of the defenders rendering them liable to be empowered in detail." How necessary, then, that the *whole* force should have locomotive power available, in order to dispose your force according to the sudden exigencies of the moment! And have the Commissioners considered that simultaneous feints divide the *enemy* equally with the *defenders;* and that the attacking force, immediately he leaves his own shores, loses the advantage of the electric telegraph, upon which facility of communication and the power of concentration depends; while for the defenders this important agent is always available on his own coast, assisted as he would be by his numerous cruisers?

Nor can I pass without exception the statement "that it is so very obvious that there are many modes in which feints could be made." These loose and general assertions are eminently vague and impracticable, and I am certain that I shall be supported by the authority of the services when I state that it is quite ignorant of the judicious mode in which such feints can be made. Indeed, the supposition of their power of concentrating their naval forces for these simultaneous feints or attacks assumes that we are ourselves in a complete state of natural paralysis, and unable to advance a single pawn to attack the many weak places which the enemy must necessarily leave exposed.

In referring to the next paragraph (9), I shall place in juxtaposition the words of the Commissioners themselves in this and their former Report:—

Second Report.	*First Report.*
(Paragraph 9) [page 560]: "Captain Coles, in his pamphlet, appears to think that the improvements in ordnance effected in the course of the last few years, combined with the introduction of steam, electric telegraph, and iron-plated vessels, will cause as great a revolution in warfare as the invention of gunpowder."	(Paragraph 3): "Since the peace of 1815, the state of naval warfare has been revolutionized." (Paragraph 19): "Of late the application of steam power to ships of war, the introduction of vessels plated with iron, and the invention of artillery of longer range and more accurate aim have rendered all defences designed for the earlier state of war incapable, without very extensive additions, of defending the places for the protection of which they were designed, and require the adoption of a style of sea-defences suited to the present state of naval warfare."

And the Commissioners ought to have added:—

What greater proof can we have of the *great revolution* now going on, than that these very forts, which were devised hardly a year since to be of granite, are now to be built of 10-inch iron?

Advancing now to paragraph 11, (page 560,) the Commissioners say: "It is obvious that if ships are to be the *sole defence*, a force must be stationed permanently at each port equal to any that may probably be brought against it in the absence of the fleet; an inferior force would evidently be no defence whatever." My answer must depend upon the construction that can be put on the words "sole defence." If the defence of the roadstead of Spithead is understood, then the question has already been answered; but if the defence of the inner harbour and its immediate outworks is alluded to, it has never been stated by me that forts were unnecessary, but much the contrary. It is the projected isolated forts *in the sea* that I condemn.

Continuing our consideration of the same paragraph :—

Second Report.	*First Report.*
(Paragraph 11) [page 560]: "These vessels must be to a considerable extent manned by sea-faring men, and commanded by naval officers, who at such a time would be better employed on board sea-going ships.	(Paragraph 24): "We submit that means might readily be found for providing these floating batteries with efficient crews at a time of expected attack, by appropriating for that purpose the officers and seamen of ships that happen to be refitting or repairing in the port, the Naval Coast Volunteers in the vicinity, and others who might be compelled to remain idle spectators at the time when their services would be of the greatest value."

It is needless to remark how contradictory these paragraphs are, and when the Commissioners say, "the number and force of the ships stationed at each port would be known," would the force not be equally known if consisting of the three forts and the few auxiliary iron ships?

Again, when the Commissioners state "that when ships must lay within a moderate distance of forts, the forts must have a superiority," they assert a truism which no one will dispute, but when ships *need* not lay within a moderate distance, and in fact it is the very reverse, the advantage will evidently lay with the side which can come and go at pleasure.

No doubt the forts designed for erection on the shoals at Spithead will be, as the Commissioners say, of a peculiarly formidable description,[1] but were each of them in itself a perfect Gibraltar, what will it matter, provided they cannot attain the object for which they are raised—that of stopping the passage of iron-protected ships hurrying past them? Although in the assumed invulnerability the men who man them may be safe, yet certainly the embrasures will be equally open to shot and shell as with the ports of a ship, so carefully pointed out by the Commissioners.

Moreover, have they ever considered the effect of the indraught of smoke through the 120 embrasures of the fort after the few first guns have been fired, and how utterly this simple contingency would paralyse the outlay of such a vast expenditure? We all know under what difficulties casemates, which are open to the rear, labour from this very cause. Ships moving through the water clear their decks by the current of air produced; but how these circular forts, stationary and closed in with mortars on their roofs, are to rid themselves of this risk of being completely blindfolded, is more than I am able to explain.

In paragraph 17, (page 561,) it is stated "that space which Captain Coles assumes is not effectually commanded by the fire from the forts." Do not the Commissioners likewise presume this by contemplating an auxiliary force of iron-cased ships, a net-work of obstructions, and powerful explosive machines to prevetn the occupation by an enemy of that space?

Paragraph 18, (page 562,) goes on to say, "the fact must not be lost sight of, that it would be easy in time of war to place a net-work of obstructions and powerful explosive machines, as contemplated in the memorandum of constructions given by us to a Committee of Naval Officers, and mentioned in the Appendix to our Report, pages 63 and 65 (see Appendix), in those positions over which it is assumed that the enemy would otherwise move with comparative impunity."

I desire to give this a complete contradiction: it must not be supposed for a moment that any one of the Committee of Naval Officers ever concurred in such a

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[1] In a foot-note, page 561, of the Commissioners' Second Report, they affirm Captain Coles seems to be labouring under the impression that these three forts at Spithead were to cost £11,000,000. This must be an oversight of the Commissioners, for I never was under such an impression, as will be seen by reference to my pamphlet. I have stated, and still feel confident, these forts will far exceed the sum named, viz., £840,000.

preposterous recommendation as covering a space over which ships could otherwise manœuvre, as will be seen by the following letter :—

DEFENCE OF PORTSMOUTH.

To the Editor of 'The Times.'

SIR,—Vice-Admiral Sir G. Sartorius, in his letter to 'The Times' of the 24th inst. exactly reverses the view of the late Sub-Committee, which he erroneously styles the Sub-Committee on "National Defences;" and he mistakes "what the Government wished to know from them."

He implies that "a recommendation was made that a complicated work of booms, chains, nets, and innumerable anchors should be spread over so large a space as Spithead, at a cost of £500,000, like a net for catching tunny fish;" and he expatiates on the difficulty of keeping all this cumbrous complication in working order in winter and storm, and on the enormous inconvenience of embarrassing this important roadstead with all this mass of materials.

So far were the Committee from recommending anything of the kind for even the passages to Spithead, that, after dwelling on the enormous cost of a floating barrier between the Horse and No Man's Land shoals, to enable it to withstand the stress of weather to which it would be subjected, they state that at high water there would still be a broad passage of sufficient depth for the largest vessels between each of the shoals and the land, which would render the barrier useless; subsequently their report states that such barriers might be efficaciously employed for *passages of moderate breadth* and exposure to the sea.

Again, Sir G. Sartorius says:—

"It seems to have escaped the attention of the Committee that the simple remedy against shot-proof vessels is to oppose them by the same kind of vessels. As these would be constructed for harbour protection alone, they could be made more powerful and handy than those of the enemy." Now, the Committee actually state that the greater portion of the vessels employed as a local force (and which they are accused of ignoring) should have a speed of not less than 10 knots, carry heavy guns protected by 4½-inch iron-plates, be at the least 2,000 tons, old measurement, and have sufficient momentum and strength to render them effectual for running into vessels."

It may by some be supposed that Sir G. Sartorius must have read the Committee's Report, and then dreamt that the suggestions were his own; but how could he have imagined that he and they had arrived at opposite conclusions, while adopting their very arguments, cannot thus be accounted for. This enigma—and not the views of the Committee—must henceforth be placed "amid all the incongruities so abundantly occurring during and since the Russian war in public matters, particularly in military or naval matters," and which have "excited the smiles" of the gallant officer.

Rear-Admiral Sir T. Maitland, the chairman of the Committee referred to, is now in command of the Pacific station. In behalf of him and his colleagues I trust to your usual fairness for the insertion of this communication.

I have the honour to be, Sir,
Your very obedient Servant,
(Signed) G. GARDINER FISHBOURNE,
Senior of the Captains on the Committee referred to.

London, Oct. 31, 1860.

The difficulties to be encountered in placing these explosive machines, the rise and fall of tide, the vast outlay they entail, their very uncertain action, and the little damage they cause under the most favourable circumstances, render their practical efficacy of very little worth in any position, as proved by the Russian war. The paragraph concludes with the following extraordinary language: "We are also of opinion, that the knowledge that such impediments were so placed would deter the enemy from making such a hazardous attempt for so uncertain an object as a distant bombardment, or partial destruction of our ships." We cannot concur, and I am sure the gallant sailors whom we have known, and always hope to know, as friends, would not be so easily intimidated.

Referring to my pamphlet, the Commissioners say :—

Second Report.	*First Report.*
(Paragraph 19) [page 562,]: "In the scheme of attack proposed, it is arranged that enemy's ships should pass between the forts on the shoals, and take up positions varying from 1,700 to 3,000 yards from the forts, and 7,000 yards from the dockyard which it is his purpose to bombard."	(Paragraph 55): "A mass of buildings occupying such an area, and containing such combustible materials as abound in Portsmouth Dockyard, can be set on fire and almost entirely destroyed, by rifled Ordnance, at a distance of 8,000 yards.
Again— "Here he must anchor; the confined space and strength of tide will render this a necessity, in order to sustain an effective fire."	(Paragraph 49): "The capacious anchorage of Spithead becomes of peculiar importance in the time of war."
"The distance at which this fire is delivered is such that little doubt need be entertained as to the certainty of striking the attacking ships."	(Paragraph 55): "An enemy's flotilla of small vessels, armed with rifled guns, might occupy Spithead and the Horse Sand, and without approaching nearer than 3,000 yards to any of the existing works, would bombard the Dockyard with comparative impunity. Such vessels would offer so small a mark at that distance that even the accuracy of the newly-invented rifled ordnance could not be depended upon for striking them; but when it is considered that each will be in motion, and that it will be impossible to estimate correctly their distance, thus continually varying, it may fairly be assumed that they would incur but little risk in such an attack."

Surely in the above the *first* Report of the Commissioners agrees rather with the pamphlet criticised than with their own *Second* Report.

By the abandonment of *two* out of the five forts first proposed, it will be seen, by reference to the map of Spithead, that vessels from that anchorage can bombard the Dockyard at a distance of 5,000 yards without being themselves within 3,000 yards of any fort, verifying the Commissioners' own statement, that vessels would occupy the Horse Sand and bombard the Dockyard at a distance of 7,000 yards, without approaching within 3,000 yards of any fort. And under those circumstances, still making use of the Commissioners' own words, they would thus "accomplish the destruction of Portsmouth Dockyard with comparative impunity."

The enormous area of the Dockyard being upwards of half a million of square yards, does away with any necessity of anchoring to sustain an accurate fire, nor is it necessary, as the Commissioners suppose, that a target of this gigantic extent should be seen at all: every shell could be thrown into it by ships moving in a circle, according to the practice at Odessa.

The Commissioners continue: "The whole of them will now be under the concentrated and undisturbed fire of the forts, from rifled guns of great accuracy and penetrating power;" but if, as clearly proved by the Commissioners' own admissions, the vessels "would be 3,000 yards from any fort, and at that distance would occupy Spithead and the Horse Sand with impunity," of what avail would be this assumed power, when we know we have not hitherto succeeded in penetrating an iron-cased ship beyond 400 yards, and even then only under conditions that would be almost impossible in a general engagement?

I cannot quit this paragraph without contrasting with each other these sentences:—

Second Report.

"Some of the heavy Armstrong projectiles carry a velocity of 700 or 800 feet a second to a distance of 4,000 yards, and would be formidable even to an iron-sided vessel anywhere within that radius."

(Paragraph 20) [page 562]: "The exact distance of each ship will have been taken by cross bearings, taken and signalised from the forts."

First Report.

(Paragraph 55): "Such vessels will offer so small a mark at that distance [3,000 yards] that even the accuracy of the newly-invented rifled ordnance could not be depended upon for striking them."

"But when it is considered that each will be in motion, and that it will be impossible to estimate correctly their distance, thus continually varying, it may be fairly assumed that they would incur but little risk in such an attack."

Here, again, I must decidedly concur in the *First* rather than in the *Second* Report of the Commissioners.

Further, with regard to the remarks the Commissioners make, when effecting a distant bombardment, ports must be so constructed as to allow for the elevations of the guns to about thirty degrees, thus exposing a large area for the entrance of shot and shell, I must remark that a simple alteration in the construction of the gun-carriage will give the necessary elevations without any additional risk.

Referring to "the perfect steadiness and accuracy" with which the fire from those forts may be carried on, the Commissioners have overlooked one obstacle through which neither the eyes of gunners nor the most powerful telescope can penetrate: this is an obstacle which should by no means be left out of the account. There is, however, in the Commissioners' Report no allusion whatever to this important consideration, and it is even stated that "the exact distance of each ship will have been ascertained by cross bearings, taken and signalised from the forts."

Perhaps the most objectionable statement of the whole Report is that referring to the effect likely to be produced by *vertical fire*. Believing I may claim some fair experience of the service, and ignorant that any such practice can be expected from mortar-shells, I have made it my business to inquire of officers in both services likely to be informed on the matter. I find my own views entirely corroborated as to the great uncertainty of vertical fire at a small object, except under the most favourable circumstances, such as a pleasant afternoon's practice on Woolwich Common. But such practice can be no criterion for guiding us in firing through the smoke and din of battle at *moveable* objects at *unknown* distances, inasmuch as the effect is entirely lost by the error of a single foot—to say nothing of the risk of striking in this potting practice our own inferior force of iron-cased ships which at this time the Commissioners intend to manœuvre under the protection of their forts—"capable of protecting a force to act at the right moment offensively against the enemy." When the commanders of this small auxiliary force, watching at a distance, see the bouquets of 13-inch shells flying gracefully in the air, they will hardly think it the *right moment* for closing. Nor will I allow the smoke to clear away without firing another shot in support of what Admiral Dundas has so cogently put forward, as is quoted in the Commissioners' First Report, par. 49,—"It should be borne in mind that in all former wars Spithead has been used as a perfectly secure rendezvous for a fleet; receiving-ships, sheer-hulks, and many other appliances for refit have been stationed there; caulking and other extensive repairs by shipwrights, artificers, and riggers have been carried on at Spithead; and no ships used ever to be allowed to proceed into harbour, merely for victualling and watering, or completing the ordinary supplies of stores and ammunition. All these operations will still require to be performed at Spithead, in addition to coaling, which will henceforth be not less important. Convoys of a hundred sail of merchant vessels at a time have been assembled at Spithead."

Let us for a moment imagine the horrid confusion and destruction which the cross-fire from these smoke-enveloped forts would create among such a multitude of our defenceless vessels, when the enemies have arrived in a line, and are perhaps purposely intermingled with them! And, moreover, considering the low angles at which these heavy guns would then be firing, it is much to be feared that the shot and shell missing their mark would create sad mischief and slaughter on our shores.

In paragraph 22 [page 563], the Commissioners remark that improvements in rifled ordnance are going on so rapidly, that they see no reason to doubt much heavier guns than these may be perfected, and that a 300 or 400-pounder may be employed in the forts. This is all in prospective. But even if this anticipation should be realised, the difficulties under which the forts labour, as shown in my former remarks, are not removed; indeed, it is by no means certain that, as the calibre is increased, the difficulties of working effectually such gigantic ordnance in smoky atmosphere against moveable objects will not be proportionately augmented.

I do not deny the probability of a still greater advance being made in the power of artillery, especially as, notwithstanding the great progress it has recently made, the resistance of protecting material has hitherto improved in a greater degree than the penetrating power of shot.

Nothing could be more ingenious than the manner in which the Commissioners evade my argument as to the paramount service which these forts would be to the ships of the enemy in their pilotage into Spithead. On this point I would refer the reader to the able Article in the 'Times' of May 11th. I will here content myself with saying, the one hour's delay, which the Commissioners admit might be involved, might, as the 'Times' truly says, "make all the difference between success and failure." The Commissioners do not appear quite to have made up their minds as to the removal of these buoys, as will be seen by the two following statements:—

Second Report.	*First Report.*
(Paragraph 23) [page 563]: "It can scarcely be contemplated that we should ever be in such a position as to be compelled to move the buoys."	(Paragraph 23): "They [floating batteries] would be serviceable also in annoying the enemy while attempting to buoy the Channel."

This certainly contemplates the removal of the buoys.

With reference to the question of relative expense between ships and forts. The cost of the 'Warrior' class brought forward in paragraph 24, [page 563,] is nothing to the point: she is a sea-going ship, and the consideration of the cost of the construction of vessels for purely local purposes should alone be fairly mooted. If the class of vessels proposed by Admiral Sir R. S. Dundas is found by experiment to answer the purpose expected of it, I shall have no hesitation in falling back upon them, and in that case the advantage of expense would be immeasurably in my favour.

Finally, let us consider the relative value of the two following remarks:—

Second Report.	*First Report.*
(Paragraph 25) [page 563]: "With the two entrances of the Solent fortified, and combined with a small force of local floating defences, the northern shores of the Isle of Wight are secure."	(Paragraph 56): No practical amount of fire from batteries can be depended upon to stop the passage of steam-ships."

Here, again, I must prefer the first thoughts of the Commissioners.

It therefore appears that having once passed the forts of Spithead, the whole of our interior shores are exposed to the attack of an enemy wherever he pleases; for the "small force of local floating batteries" venturing beyond the range of the forts will be, as the Commissioners describe, overpowered by the superior number of the enemy; for, though unwilling so continually to turn the guns of the Commissioners against themselves, I cannot avoid quoting the following words. (Paragraph 26) [page 564]: "Again, if the defence of Spithead be reduced to the few iron-cased ships proposed, an enemy superior in naval means at the moment might throw a force on shore to the westward of the Gosport line of defences. In short, during the temporary absence of our fleet, we practically abandon the Solent to the enemy."

I perceive in the Appendix that the authority of the Inspector-General of Fortifications and the testimony of Sir William Armstrong were called in aid a month or two after the Commissioners' Report was written. There is nothing in these documents but what I believe will find an answer in the body of my remarks.

Sir John Burgoyne, in his anxiety to depreciate the power of resistance of iron-cased ships, refers to a newly-invented missile, which at any rate has not received the sanction of the Ordnance Select Committee. He describes it as a shot with a receptacle in its rear for a charge of powder—with fuse and all complete. Fixing the fuse at the end of the shell nearest the powder is a novel idea of itself, but what are we to say of the adjustment of the centre of gravity? and the eccentric gyrations which the projectile must necessarily take in its flight? In plain language, it would 'wabble' round its axis; and the line of its trajectory could not be depended on.

With reference to Sir William Armstrong's letter to the Commissioners, I have little to say. He makes an important public statement, and his reply to a request for explanation can hardly be deemed satisfactory. I therefore insert the correspondence. (See Appendix.) [Page 581.]

I desire to remind my readers that the relative effects which can be produced by forts and ships must, it is conceived, be estimated in argument as follows :—

FORTS.

A fort fixed and immoveable has only one power of destruction limited to the range of its guns, which is only practically dangerous in that sense when ships permit themselves to be drawn within a radius of 600 yards.

IRON-CASED SHIPS,

Which are practically forts, with the inestimable advantage of *mobility*, can—

1st. Fix themselves in the most advantageous position.

2nd. Enter action under obvious advantages of time and position.

3rd. Avoid action if necessary.

4th. Close with the adversary.

5th. Run into the enemy as steam rams.

6th. Board the enemy.

7th. Rapidly reinforce a weaker part of the action, or carry assistance to where required.

8th. Move out of their own smoke.

9th. Present themselves obliquely to the fire of the forts without destroying in any way the efficacy of their own guns.

10th. By their power of motion, destroy all chance of accurate aim on the part of the forts.

The elaborate plan of the Commissioners, to be effective, requires the successful co-operation of three agents, viz., Forts, Auxiliary Iron Ships, and a net-work of obstructions and explosive machines, which it has been already shown paralyse each other immediately the enemy is among your own shipping. The plan proposed by Admiral Dundas and in my pamphlet depends upon one recognised most formidable engine of war, viz., iron-cased ships to meet vessels of the like nature.

The question, therefore, becomes thus filtered down into this small but essential residue : the possibility of iron-cased ships passing the gauntlet of forts planted on the shoals at Spithead—forts which will act as certain guides and beacons by day or night to the advancing enemy; which even the Commissioners allow, to be really effective in penetrating the sides of the armadillo fleet, must finally be mounted with cannon the construction of which is still a secret in the womb of time, and which, from a blinding cause utterly beyond any known means of control, would be impotent at the momentous crisis which they were designed to control. I have shown very plainly the contradictions and inconsistencies of the two Reports issued by the Commissioners, and the great absence of practical bearing. I am happy in knowing that I am supported in my views by the great bulk of the officers of the service, and am now content to leave the decision in the hands of those from whom this great nation will expect a calm consideration of the best means available for protecting her interests from destruction, or even insult.

LETTER from CAPTAIN COLES to SIR W. ARMSTRONG.

United Service Club, May 18th, 1861.

DEAR SIR,—In your letter to the Under-Secretary-of-War on the relative merits of ports and floating batteries, (having reference to the Report of the Royal Commissioners on National Defences), you observe that special modes of construction, such as that proposed by Captain Coles to afford protection to the gun, would involve increased difficulties of construction and navigation.

I regret that I have not yet had an opportunity of showing you my models of ships, as I have been desirous of doing, as you would, on inspection of them, at once perceive that no extraordinary difficulties of construction are in any way to be apprehended, and that, in regard to the suitableness for navigation, no deviation is proposed in vessels carrying my shield from the outer form of ordinary vessels.

I should feel obliged by your informing me of the nature of the difficulties which you apprehend, especially of those relating to the *navigation* of vessels fitted with my shield.

Yours very truly,
COWPER P. COLES.

[REPLY.]

Newcastle-on-Tyne, 22nd May, 1861.

MY DEAR CAPTAIN COLES,—I may be mistaken, but it certainly does appear to me that the more you deviate from the normal construction of a ship with a view of rendering her proof against shot, the more you will increase both the difficulty of construction and the difficulty of navigation. I cannot pretend, however, to be a high authority upon such a point, and what I have stated will go for what it is good for, and nothing more.

Very truly yours,
(Signed) W. G. ARMSTRONG.

Captain Coles, R.N.

LETTER from CAPTAIN SHERARD OSBORNE, C.B., of H.M.S. 'Donegal,' 101 guns, to CAPTAIN COWPER P. COLES.

MY DEAR COLES,—I say that the 'Donegal' under steam, drawing 27 feet water, shall rattle about the waters of Spithead at 8 knots an hour—hit the dockyard every time with her 100-pounders, and that not one in two hundred shots shall hit her; that as to mortar shells, the air will have to be filled with such falling projectiles to insure lodging one on her decks; and that all the engineers in all the forts shall fail to give her range or position for more than one minute at a time. Her change of position would be thus:— 8 knots = 2,000 yards × 8 = 16,000 yards per 60 minutes, *or* 266 *yards per minute!* or the one-eighth of a mile geographical.

Yours very truly,
(Signed) S. OSBORNE.

LETTER from COLONEL ALEXANDER, C.B., R.M.A., to CAPTAIN COWPER P. COLES, R.N.

Forton, May 28th, 1861.

MY DEAR COLES,—It is my belief that the expectations we are led to indulge in respecting the effects to be produced by horizontal fire against distant objects will never be realised, and the following are my reasons for having come to this conclusion:—

Even when these objects are stationary, and the distance from them accurately known, the first shots are always liable to be thrown away, from a proper allowance not having been made for the strength or direction of the wind, or from some other accidental cause; for it has to be borne in mind, that, however perfect we may make our military machines, there is a limit to the powers of those who use them.

When firing at a moving object at an unknown distance, I think, in the event of it advancing towards him, the practical artilleryman would wait until the range was sufficiently reduced, to permit of his watching the direction and effect of his fire, and ensure the penetration of the projectile—when firing against iron-sided ships—on its striking.

Picking up the range by trial shots, when firing to seaward, is no easy matter; for, from the rear of the gun, it is very difficult to form an approximation of the distance at which the shot falls short of, or passes beyond the object.

A ship steaming past a battery may be considered as moving along the tangent of an arc, to which her shortest distance from the battery is the radius, any other distance being the measure of the secant of the angle which her course subtends; so that the artilleryman, in laying his gun, has not only to allow for the time taken by the projectile in its passage through the air before it reaches an object which is moving at a rapid, but an unknown rate, but to alter his elevation at each round so as to allow for a variable increase of range. Skill and constant practice may enable him to do this, but he will always have the mortification of knowing, that except when the ship is actually abreast of the battery, the shot must strike her at an angle, which will become more and more oblique, until its power of penetration is entirely destroyed.

Vertical fire from mortars against a small object at a long range, even when that object is immoveable, is a mere matter of chance, dependent upon the number of shells thrown within a given area, and as the size of this area is in proportion to the length of the range, the more distant the object, the greater number of shells we shall have to throw before we hit our mark; when the same object is in motion, the chance of hitting it is necessarily diminished; and it has to be objected to vertical fire, that any naval operations against the enemy likely to be exposed to its effects would be out of the question.

There is another difficulty connected with distant horizontal firing, which I must not forget to mention.

Unless under certain exceptional atmospherical conditions, it is not possible to keep up a rapid continuous fire against a distant object, from a number of guns brought together in a battery, whether the battery is casemated or not: there is no getting rid of smoke; it will stick by us whether we like it or not. At Kinburn, I happened to be in a line-of-battle ship, anchored within 1,200 yards of an open battery, from which a well-sustained fire was kept up for some time, but not a shot struck us, and I could attribute it to no other cause: it was most certainly from the ship having been so completely enveloped in smoke that the battery received so little injury in return. Had the duel been quietly fought out with single guns, much more harm would have been done on both sides.

I conceive that one of the great advantages which a system of iron ships for home defence holds out over the most perfect plan of fortifications that can be devised is, that on the enemy appearing, he could be met at such a distance as would render it certain, that not a shot from one of the formidable guns which science is about to give us would be thrown away. What, may I ask, will be the use of security if, whilst we enjoy it under the shelter of our forts, the enemy might amuse himself by capturing within sight of our strongholds every stray ship he came across?

The admirably-contrived forts upon which we might have spent so many millions, and the hundreds of skilled artillerymen imprisoned within their walls, could not save us from such a humiliation.

I believe that the safety of England must be made to rest on the number and strength of her iron ships; and I sincerely trust that your unremitting efforts in connection with this important subject may be crowned with success.

Believe me to remain,
Yours very sincerely,
J. G. ALEXANDER.

To Captain Cowper P. Coles, R.N.

EXTRACT of a LETTER, from MAJOR R. B. MCCREA, of the Royal Artillery.

AFTER attentive consideration of the arguments advanced by the Commissioners in their Second Report, I think that an opinion upon those points, which have a professional and practical bearing, will best assist the labour you have so much at heart. Nothing can be more startling than the statement made respecting the value of vertical fire. I am aware that, under circumstances where the range is accurately known, the target large and stationary, the wind light and favourable, a certain result from mortar-shells may be expected; but the case is very different when the target is moveable, the distance uncertain, the enemy unseen. Under the circumstances proposed by the Commissioners, there would be about as much chance of dropping shells on the decks of moving ships in action as a man might have of pitching peas into the pockets of a revolving billiard-table. This is altogether independent of the extreme danger of injuring our own auxiliary ships as they approach to close action. It will be impossible for gunners on shore, amid clouds of smoke, to distinguish friend from foe; and it must not be forgotten that vertical fire, to take effect on a small given area, is eminently unsatisfactory—far more so on water than on land. In the latter, the destructive power is likely to be felt in some way or other; in the former, if it do not hit the exact object, the result is nil. Without speaking positively, I do not estimate the terminal velocity of a falling shell above 700 or 800 feet a second; and I question much if the acquired momentum will smash in the arched iron deck of a modern ship-of-war, more particularly if such a deck (being without guns) be protected by a thick layer of mantlets or hammocks. In the defence of a great naval arsenal from destruction, it would not do to depend upon "expectation" or "probability of striking;" we must be sure of the result which our fire will produce. That of a vertical nature seaward is of very little value; nor can I estimate a whit higher cross-bearings of the distances taken and answered amid clouds of enveloping smoke. *Credat Judæus!*

It is hard to say on what grounds the Commissioners assume that rifled guns would be so formidable to an iron-sided vessel at a range of 4,000 yards. So far as experiment can be a guide, we know that at present, with 4½-inch plates, such ships are practically invulnerable beyond 600 yards; and the effect which has been produced against upright sides has been so with the enormous advantage of firing perpendicularly at the target. Considering the facility with which such ships may oblique themselves to the fire of the forts, we may fairly consider that the probabilities of their being crippled or destroyed when placed at a range beyond 600 yards as very remote indeed. This is quite independent of motion, smoke, and uncertainty of distance; all points in their favour, and reducing their risk almost to zero.

When Sir John Burgoyne, in alluding to the fire on steamers approaching the forts at a speed of 10 or 12 knots, at a distance of 2,000 to 3,000 yards, says, "the only difficulty is in the length of range, or accuracy of elevation according to distance," he does but scant justice to *the difficulty* in question, which, in fact, is almost insurmountable. It is by no means an easy matter to ascertain the effect of shot from a battery at that distance; but when it is remembered that, amid the din, confusion, and smoke, the range is to be continually changed by pure guess-work, and the result dependent, not upon anything like reliable, substantial action, but upon the chance amount of skill or brains which individuals may possess; let us estimate such fire fairly—for what it is worth, and for nothing more. It will assuredly do very little injury to an iron fleet rapidly approaching. The only way in which I can understand that forts can be dangerous, is when the ships passing between them are exposed to their direct cross-fire. Then a number of guns concentrated on a given point, and fired by electricity, might sink one leading ship; but that is all. And even then there are a good many chances in favour of this forlorn hope: distance, uncertainty of exact range (for it must be very exact), haziness produced by smoke, and, above all, the possibility of the iron sides of the target being defended by mantlets or some compressible matter—a fact at present quite undeveloped. Moreover, for the purpose of this one great broadside, iron ships anchored would do as well as forts, with the inestimable advantage of being able to slip and follow up the eluding enemy, and place themselves with him at once on equal terms. Again, the enemy's ships once passed, the forts must cease firing, or else the carnage which will ensue among the merchant navy and dockyard property at Spithead, as well as on our own shores, will be deplorable. I place no faith whatever on the explosive mines which are to obstruct the channel; and it is clear that if they are effective to obstruct, they might be left to do it without the forts at all. In mines on shore, with vast resistance to overcome, the effect produced by explosion is very great; but the elasticity (not of the particles but of a body) of water destroys or wastes the effect of the powder; and I think the chances of blowing out the bottom of a ship-of-war in this way must be small indeed. Sir John Burgoyne's new shell, never having been tried or made as yet, has no claim for notice in argument, further than to say, that if you understand its supposed merit of construction, I confess I do not.

The question between forts and ships cannot be considered abstractedly as a question of expense. If it were positively ascertained that the former were far better than the latter, or that they really could do their work, and prevent the entrance of an enemy to Spithead, I do not believe the country would cavil at any estimate, however enormous. Nor is a high value to be placed on the fact that these forts can be themselves made invulnerable. It is not the amount of safety to the gunners within their *enceinte*, but the damage they can cause in so many minutes to an enemy, under circumstances of especial difficulty, which alone must be considered. Their merits weighed in this balance are found wanting.

Iron-cased ships, or forts in motion, can alone contend with a reasonable chance of success against similar forts in motion. If Tom Sayers were strapped to a post (*very tight*), and you and I were allowed to dodge round him, we might fight uncommonly well, and really think we were going to thrash the champion; but if the cords happened to break by any mischance, and Tom got loose, I know what I should do; and when you write, please say what you would do. It is not unlikely but that our opinions will coincide on this point, and that we should both "live to fight another day."

You will, I am sure, not fail to notice the many discrepancies and contradictions contained in the two Reports; so that I will not allude to them further than to say that Sir William Armstrong evidently noticed that one relative to the anchoring of the ships, or rather the necessity of it. His "if" is very significative, and I should have thought might have been "as good as a nod," on the point. I have heard many naval officers discuss the question, all unanimous in the practicability of, and enormous advantage obtainable by, motion. On this point you are a far better judge than I can pretend to be.

Let me briefly draw your attention to the statement of the Commissioners relative to the power possessed by an enemy of making feints or simultaneous attacks. If we are at all his equal in strength, he must be very chary in using this expedient; but supposing he risks all exposure of his own defences and concentrates upon us, it must be for the sake of some grand *coup*, such as bombarding Portsmouth or Plymouth Dockyard. It would in modern times hardly be for anything less. And this brings us to the consideration as to whether it really is worth while to expend such vast sums (with the range of artillery constantly increasing) in fortifying by land *a dockyard within shelling distance of the sea.* If the passage across Southampton Water at Calshot Castle could be made impassable, so as to secure a dockyard eight miles up at Southampton, where our future iron navy could securely retreat and repair, then the value of such an outlay, however vast, might be well appreciated by the nation. But admitting the just value of Portsmouth Dockyard in the building and repair of wooden ships, as well as in its central situation in the Channel, still in the fast-approaching age of iron, its worth must diminish: for if our fleet were driven back after a defeat, the forges and anvils of Portsmouth will not be able to recover such a disaster, as they would the repairs of wooden ships. But supposing the jewel to be really worth this costly setting, that is an additional reason why it should be removed beyond the risk of destruction; or, in other words, the *incentive* for those feints should no longer be so alluring as to leave national property of vital importance within the reach, from the great and common highway, of modern weapons of destruction. I do not mean to say that forts or batteries at the entrance of narrow channels and mercantile harbours are ill-placed: to a certain extent these are necessary. But looking to the same line of argument which tells so in favour of moveable against fixed forts, I think the present scheme of defence, which sets so high a value on fortifications, is fixed on a wrong foundation altogether. Instead of those immense sums to be spent on immoveable casemated forts and batteries, guarding limited areas of coast, would it not be wiser to utilise our means towards defensive powers which can be made available in any direction; to secure, in fact, an *overpowering field artillery* and rifle-fire; and to assure the possibility of rapid concentration by branch lines of rail and good roads for troops on such parts of the coast affording peculiar facilities for landing; with a good military road fit for field artillery running parallel with the shore in such places. It is the landing, and entrenching, and securing of his communications, on the part of an enemy, that must be utterly prevented. If not, in such a free country as this, it will be sorry work falling back upon a few fortresses, however strong; and even to contemplate this we must have lost the Channel beyond the power of any Portsmouth to repair the disaster. And referring again to the fortifications now throwing up, say at Sandown in the Isle of Wight, it appears hard to understand their proposed utility. For without a complete command of the Channel, and the ability to secure his communications, an enemy dare not attempt a landing with a view of dragging across such enormous guns as would bombard the dockyard. This would be a matter of time, during which, even if securely entrenched, how is he to be provisioned? On the other hand, if he commanded the Channel, he would not land there with such trouble; and I am of opinion that if he were able to make good his seizin of the soil anywhere along the southern coast, and to drag up such weight of guns, ammunition, provisions, &c., as would enable him to lay siege to the strongest forts we could build on Portsdown Hill, without our being able to prevent him, THE GAME IS UP; and their reduction is only a matter of time, of far less importance. Therefore the fortification of Portsdown Hill, excepting by field-works, such as troops for the sake of instruction could throw up, and which would prevent an unlikely *coup-de-main*, is, I humbly conceive, an error in judgment.

Have the Commissioners considered how completely 'bonnetted' these ocean forts may be in their own smoke, and how helpless the best skill of gunnery becomes under such circumstances? It is to be feared not; and I know no means by which a stationary battery can be cleared of its blinding canopy, while a ship with moving power can circulate a ventilation through her decks, or move out of enveloping clouds. Only imagine the confusion into which the men who are stationed to take the cross-bearings of the distances will fall (even if they can see), when trying to distinguish between ships moving about like flies on a sunny pane of glass! Had a photographer been added, our preparations for battle, victory, and eventual fame would have been most complete!

An universal acknowledgment of the talent with which the First Report was drawn up followed immediately on its publication; but it is to be doubted whether the dragging of the Second Report into light should be a subject of rejoicing. The apologetic character which it bears has not escaped the notice of the press; and that must needs be a weak cause which requires propping up by expectation, probability, vertical fire, explosive machines, and cross-bearings in smoke; and, even when constructed, is proposed to be armed with guns which have never yet been in existence. Apart from disagreeing entirely with arguments based on such conclusions as these, and believing that the money spent on these immoveable constructions will be as entirely wasted, as they are opposed to the spirit of the science of modern warfare, I chiefly regret those sentences in the Report which apparently disparage the skill and enterprise of a brave and gallant enemy, in the supposition that a knowledge of the position of explosive machines, or such-like martial puerilities, would deter his fleet from their intention to attack. This is too much on the painted-tiger and pea-in-bladder principles of our late enemy John Chinaman; and will be as little indorsed on this side of the water as it will be sneered at on the other.

When that eminent engineer, Sir John Burgoyne, in speaking of the assumed power of iron ships to resist shot, says, "Scattered shot of the ordinary character even from heavy calibres, from rifled as well as the old kind, *and at short ranges*, have failed to penetrate:" what then, we may ask, is the use of heavy guns mounted in batteries along the lines round Portsmouth, which are to play upon ships, if the range is even 600 yards, which in most places it vastly exceeds? If the shot will not penetrate in quiet experimental trials at short distances, with every advantage in their favour, how will they in action at long distances with many points in favour of the enemy? This does not apply to howitzers or to light guns mounted to keep off troops from landing, or boat attacks, which heavy guns can never do. In short, the defence of the attack has suddenly become stronger than the power of attack from the defenders, and, as the subject is quite in its infancy, is likely to become much stronger. To cling, therefore, to the old rules of fixed fortifications in isolated forts to meet a winged enemy almost invulnerable in his armour, is simply to throw away the opportunity of remodelling our schemes of national defence in accordance with the great power of mobility which modern science is developing, and to prepare to fight him on such unequal terms as will court national humiliation. I sincerely trust the efforts which you are now making will induce the Government to pause before closing the contracts; and cannot but believe that, were a new Commission appointed to re-consider this vital question, a very different verdict would be delivered. In this hope, and with every wish for your success,

I am, my dear Coles,
Very faithfully yours,
R. B. McCrea.

Portsmouth, May, 1861.

April 30, and May 7, 14, and 28, 1861.

GEORGE PARKER BIDDER, President, in the Chair.

The discussion upon the Paper, No. 1,038, on "The National Defences," by Mr. G. P. Bidder, jun., was continued throughout these evenings, to the exclusion of any other subject.

At the Meeting of May 7, the following Candidates were balloted for and duly elected:—Lieutenant-Colonel THOMAS BERNARD COLLINSON, R. E., CHARLES PHILIP COTTON, WILLIAM STUBBS, JULIAN HORN TOLMÉ, and JOHN MORTON TOWLER, as Associates.

At the Meeting of May 14, it was resolved, unanimously "That in order to insure a fuller attendance of Members than could be obtained on Whit Tuesday the Meeting should be adjourned until Tuesday evening, May 28."

At the Meeting of May 28, the following Candidates were balloted for and duly elected:—JEROME BURNS, ROBERT MORRISON, THOMAS ORMISTON, JOHN PATON, and PERCY GRAHAM BUCHANAN WESTMACOTT, as Members; CHARLES DENTON ABEL, Major JULIUS GEORGE MEDLEY, B.E., WILLIAM JOPLING NESHAM, and MURRELL ROBINSON ROBINSON, as Associates.

June 4, 1861.

The Session was concluded by a CONVERSAZIONE, at which the President received the Members of the Institution, and a numerous circle of distinguished visitors. The rooms were decorated with many choice works of art, and there was also exhibited a large and interesting collection of mechanical models.

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